Investigation of Transient Heat Transfer in a Rectangular Packed Duct with Asymmetric Heating

by

Mohammed S. Al-Gallaf

A Thesis Presented to the

FACULTY OF THE COLLEGE OF GRADUATE STUDIES

KING FAHD UNIVERSITY OF PETROLEUM & MINERALS

DHAHRAN, SAUDI ARABIA

In Partial Fulfillment of the
Requirements for the Degree of

MASTER OF SCIENCE

In

CHEMICAL ENGINEERING

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This Thesis is Dedicated to My Family For Their True Love, Patience and Encouraging Support

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Praise and gratitude be to Allah " he who taught the use of the pen, taught the man that which he know not."

In acknowledgement, I would like to express my great appreciation to KFUPM, Collage of Graduate Studies and Chemical Engineering Department who offer me the opportunity to do my M.S.

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التخصص : الهندسة الكيميائية

تأريخ الرسالة : ديسمبر، ١٩٩٨

تبحث هذه الدراسة في الانتقال الحملي الغير مستقر للحرارة في قناة مستطيلة محشوة ذات تسخين غير متناظر. إن هذا البحث يتناول الدراسة التجريبية والنظرية لموضوعه. لقد تم تنفيذ التجارب في قناة مستطيلة محشوة ، و إن نسبة العرض للارتفاع لهذه القناة تساوي ٤. لقد تم استخدام نوعان من مواد الحشو في هذه التجارب. النوع الأول يتكون من مادة البوليستايرين الممددة ذات شكل كروي بثلاثة أحجام مختلفة، و النوع الآخر عبارة عن حجمين مختلفين من حلقات البلاستيك المقوى. اجريت التجارب بتزويد كمية حرارة ثابتة إلى السطح العلوي تتراوح ما بين ٢٠ إلى ٢٤٣ وات/م^{٢} و رقم رينولدز ما بين ٣٠٠ إلى ١٥٥٠.

التحليل النظري للموضوع كان مستند على حل معادلة الطور الواحد للنموذج الرياضي شبه المتجانس. لقد حل النموذج الرياضي باستخدام طريقة التجميع المتعامد الرقمية. أظهرت المقارنة بين درجات حرارة الهواء داخل الوعاء الناتجة من حل المعادلة الرياضية بتلك المقاسة بشكل تجريبي، فعالية النموذج الرياضي المستخدم لوصف الانتقال الحراري الغير مستقر في الأوعية المحشوة ذات التسخين اللامتناظر. لقد تم دراسة تأثير شكل، وحجم مواد الحشو المستخدمة في الوعاء، و رقم رينولدز على نقل الحرارة الغير مستقرة. بينت الدراسة أن شكل المواد المستخدمة لا يؤثر على نقل الحرارة ولا على الوقت اللازم للوصول إلى درجة الحرارة الثابتة، كما أن حجم المواد المستخدمة للحشو لا يؤثر على الوقت اللازم للوصول إلى المرحلة المستقرة، بينما لوحظ أن درجة حرارة الهواء قد ارتفعت قليلا عند استخدام مواد حشو صغيرة الحجم. لقد بينت الدراسة أيضا أن الانتقال الحراري الغير مستقر يتناسب عكسيا مع رقم رينولدز. كلما تناقص رقم رينولدز، ازدادت درجة حرارة الهواء، وكذلك الوقت اللازم للوصول إلى المرحلة المستقرة.

لقد أوضحت الدراسة أهمية الانتشار المحوري في عملية الانتقال الحراري الغير مستقر في قناة مستطيلة محشوة و التي تنساب من خلال سطحها العلوي كمية حرارة ثابتة بينما أسطحها الأخرى معزولة. استنتج أن الانتشار المحوري هام في بداية الوقت لعملية الانتقال الحراري، بينما درجة الأهمية تتناقص كلما وصلنا إلى المرحلة المستقرة، كما وجد أيضا أن أهمية الانتشار المحوري تقل تدريجيا كلما قل رقم رينولدز.

درجة الماجستير في العلوم

جامعة الملك فهد للبترول و المعادن

الظهران ، المملكة العربية السعودية

ديسمبر، ١٩٩٨

THESIS ABSTRACT

NAME OF STUDENT	**:**	MOHAMMED S. AL-QALLAF
TITLE OF STUDY	**:**	Investigation of Transient Heat Transfer in a Rectangular Packed Duct with Asymmetric Heating.
MAJOR FIELD	**:**	Chemical Engineering
DATE OF DEGREE	**:**	December, 1998

This study investigated the transient convection heat transfer in a rectangular packed duct with asymmetric heating. The study involved both experimental and theoretical works. The experiments have been conducted in a rectangular packed duct with aspect ratio W/H of 4. Two different types of packing material have been used in the experiments, three sizes of expanded polystyrene spheres and two sizes of polyvinyl chloride Rashig Ring. The experimental runs for the different packing were conducted with heat flux in the range 20 to 243 W/m^2 and Reynolds number in the range of 300 to 1550.

The theoretical analysis of the problem was based on solving the one phase pseudo-homogeneous mathematical model. The model was solved numerically using the method of orthogonal collocation. The predicted air temperature trends were compared with those measured experimentally and they have shown a good agreement. The effect of shape, size of packing and Reynolds number on transient heat transfer was studied. It was found that the shape of packing has neither effect on heat transfer nor the time required to reach steady state. The size of packing has no effect on the time needed to reach steady state, however, the air temperature has shown a slight improvement when small particles were used. As Reynolds number decreases, the time required to reach steady state increases.

The study also investigated the significance of axial dispersion on the transient heat transfer process in a packed rectangular duct with heated top wall by a uniform heat flux and insulated bottom wall. It was concluded that the axial dispersion is significant in the early time and the degree of significance decreases as steady state is reached. It was found also that the significance of axial dispersion decreases as Reynolds number decreases.

MASTER OF SCIENCE DEGREE
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CHAPTER 1

INTRODUCTION

The study of the forced convection heat transfer in packed rectangular and cylindrical ducts is of a great interest in the field of chemical engineering. It is important in the design of the fixed bed reactor tubes (Kulkarni and Doraiswamy, 1980; Paterson and Carberry, 1983; Cresswell, 1986; Borkink and Westerterp, 1994). It is also important for the solar heating systems (Demirel and Kunc, 1987; and Choudury and Garg, 1993). The knowledge of the convection heat transfer in packed ducts is also important in the design of heat exchangers (Poulikakos and Renken, 1987) and, catalytic and nuclear reactors and the cooling system of electronic components (Alkam and Al-Nimr, 1998). Despite the importance of the convection heat transfer study in packed ducts, limited experimental work has been published for a rectangular packed duct with asymmetric heating (Cheng et al, 1988).

Air as a heat exchange medium is widely used in the heat transfer devices due to its indelicate operating conditions and less corrosion in the heat transfer equipment leading to a longer service life. Because of the low value of the heat transfer coefficient from the wall to the fluid air compared with that for liquids, the radial heat transport in a wall heated or cooled tubular reactor and other heat exchanging equipment is relatively low. To increase the transfer of heat from the heated wall to the airflow, packing is introduced into the air passage. The packing will cause a mixing process which is a result of the deflection of the fluid by the solid material and it prevents the developing of the slow moving layers of the air flowing close to the wall and therefore increases the wall to air heat transfer coefficient. The heat transfer coefficient for the packed duct will reach a maximum at a certain ratio of the tube to the packing diameter (d_t/d_p) for different flow regimes. Wellauer et al. (1982) suggested that the overall heat transfer coefficient reaches a maximum when (d_t/d_p) is close to five while Dixon (1988) showed that the maximum overall heat transfer coefficient would occur at (d_t/d_p) approximately equal to eight. The overall heat transfer coefficient in a packed duct was reported to increase linearly with the superficial mass flow rate.

Due to the high rate of heat transfer in packed ducts, several investigations have been conducted to analyze the behavior of the packed systems. In 1931, Colburn studied the forced convection heat transfer in a packed tube and it was concluded that the heat transfer taking place in a packed tube is about eight times higher than that of an empty tube. However, it was reported recently, as three times higher for a forced convection heat transfer in a packed channel with asymmetric heating (Demirel, 1989; Hwang and Cheng, 1992). Makkawi (1995) and Abu Al-Saud (1997) found in their investigation of the steady state behavior of convection heat transfer in a rectangular packed duct with asymmetric heating, that the Nusselt number (*Nu)* has shown an increase of about three times higher for a packed duct compared with that of an empty one. This increase in the heat transfer rate was attributed to the mixing of the fluid air caused by the presence of the solid packing.

The effectiveness of the packing material on the heat transfer process in a packed duct depends on the shape and size of packing material. The smaller the solid particles the better the mixing effects that will enhance the heat transfer. However the smaller the size of the packing the more the pressure drop along the bed and the effect of the stagnant film around the packing will increase leading to a lower heat transfer rate. The shape of the packing particles plays an effective role in the rate of heat transfer. Dixon (1988) showed that the value of the heat transfer coefficient in a packed duct using spherical packing was 20-25 % lower compared to that of cylindrical packing of the same thermal conductivity and size. It was also reported that there is no significant effects for the solid cylinders over the hollow cylinders (Rashig rings) on the heat transfer. However the Rashig rings will give a better performance due to the lower pressure drop. The heat transfer in a packed duct is directly proportional to the flow of air. It is also required to have enough pressure drop along the duct to ensure a good distribution of air across the duct. However, the pressure drop should be moderate to make the system more cost effective (Makkawi, 1995).

The transient temperature response is also important in the design of packed beds. In 1986, the transient behavior of a laminar forced convection of Newtonian fluids inside empty circular ducts and parallel plate channels subjected to a step change in the wall temperature was studied (Cotta and Ozisik, 1986). Sucec (1987) developed an exact solution for the transient conjugated heat transfer in the thermal entrance region of an empty rectangular duct with a step change in the ambient temperature outside the duct. The problem of a steady laminar constant property flow in a parallel plate empty duct when a transient is initiated by a sudden change in the duct wall temperature was studied by Sucec and Radely (1990). Kakac et al. (1990) presented a theoretical and experimental analysis for the transient laminar forced convection inside an empty channel with a fully developed flow subjected to a periodic change in the inlet temperature. The solution of the problem was developed using the classical integral transform. Joovey and

Dayen (1985) introduced an analytical solution using the two-phase model for the transient distribution of the temperature in a porous bed subjected to a step change in the inlet fluid temperature. Al-Nimr et al. (1994) investigated in two separate studies the transient behavior of a forced convection heat transfer in the entrance region of a cylindrical porous medium and a porous concentric annulus with developing boundary layers. The problems were solved numerically using the finite difference method. In the analysis of the transient convection heat transfer, the solution was presented for the fluid bulk temperature and the local Nusselt number along the duct as a function of position and time.

The axial dispersion of heat is usually neglected from the energy balance equation during the study of the steady state heat transfer in packed ducts. However, the axial dispersion needs to be taken into account in the dynamic analysis of the heat transport process described by the pseudo-homogeneous model (Borkink and Westerterp, 1992).

In the present work, the transient forced convection heat transfer in a rectangular packed duct with asymmetric heating has been studied experimentally and numerically. The problem solution is based on the pseudo-homogenous model, which makes no distinction between the fluid and solid temperatures. The experimental data obtained is compared with those predicted by the pseudo-homogeneous model. The transient temperature trend is presented graphically for the local axial and radial temperature inside the packed duct for different heat and flow inputs. The significance of the axial dispersion in the study of the dynamic behavior of convection heat transfer in a rectangular packed duct with asymmetric heating is also analyzed.

CHAPTER 2

LITERATURE REVIEW AND OBJECTIVES

2.1 Introduction

Due to the importance of convection heat transfer in packed rectangular and cylindrical ducts, it has been widely studied. It is important in the design of solar heating systems, heat exchangers, catalytic and nuclear reactors and the cooling system of electronic components. The study of convection heat transfer in packed ducts has been studied intensively for the last six decades. Colburn, in 1931, reported that the wall to air heat transfer coefficient can be increased by eight times when using a special packing. More recent study for the steady state convection heat transfer in a packed rectangular channel with asymmetric heating, indicates that the Nusselt number can be increased by three times (Makkawi, 1995 and Abu-Saud, 1997).

Despite the importance of transient convective heat transfer in packed ducts, a review of literature revealed that most of the available studies are interested in the steady state behavior of these systems. The dynamic behavior of a forced convection heat transfer is important in the start up and ending operation of heat transfer equipment and the design of the control systems of heat exchangers and other related systems (Cotta & Ozisik, 1986;

Sucec, 1987). Most of the transient heat transfer studies were carried out for empty cylindrical and rectangular geometry, and a limited number for the transient convection heat transfer in packed rectangular ducts. The following is a brief summary of the literature found for the transient convection heat transfer in both empty and packed ducts.

2.2 Transient Heat Transfer in Empty Ducts

Cotta and Ozisik (1986) studied the transient laminar forced convection of Newtonian fluids inside empty circular ducts and parallel plate channels subjected to step-wise variations of wall temperature. Classical Laplace transforms techniques and second order finite difference method was used for the solution. Results for local Nusselt number, average fluid temperature and the wall heat flux over a wide range of axial coordinate are presented. Sucec (1987) developed an exact solution for the transient conjugated heat transfer in the thermal entrance region of a parallel plate empty duct with a step change in the ambient temperature outside the duct. Laplace transformation was used for the solution. Comparison between the exact solution for the entrance region, the quasi-steady solution and finite difference solution was presented. Kakac et al. (1990) presented a theoretical and experimental study for the transient laminar forced convection inside an empty parallel plate channel with a fully developed flow subjected to a periodic variation of the inlet temperature. The rectangular duct used has an aspect ratio of 10 (254 x 25.4mm). The solution for the problem is developed using the classical integral transformation. Sucec and Radely (1990) studied analytically the problem of steady, laminar constant property flow in a parallel plate empty duct when a transient is initiated by a sudden change in the duct wall temperature. Viscous dissipation effects and axial conduction within the fluid were neglected. General expressions for the surface heat flux and the bulk mean temperature were derived using Laplace's transform. Nguyen and Maclaine-Cross (1991) introduced a numerical solution to the problem of simultaneously developing laminar flow forced convection heat transfer in the entrance region of thin empty parallel plates. The Nusselt number and thermal entrance length are presented for Reynolds numbers between 40-2000; Pr = 0.2,0.7, 2, 7,10 and 100; and for both constant wall temperature and constant heat flux boundary conditions. Kakac and Weigong (1993) studied theoretically and experimentally the behavior of turbulent forced convection heat transfer between two empty parallel plates subjected to a sinusoidally varying inlet temperature. The rectangular duct used was of aspect ratio 10 (254 x 25.4 mm). The air flow is hydrodynamically fully developed turbulent flow. They concluded that the heat transport in the turbulent flow is greater than that in laminar flow. More heat is transferred from flowing fluid to the wall. The theoretical model and the experimental data were found of acceptable agreement. Guedes and Ozisik (1994) presented a solution for the problem of transient forced convection heat transfer in a simultaneously developing laminar flow inside an empty channel with a step change in the fluid inlet temperature. The fluid bulk temperature and the local Nusselt number along the channel were presented.

2.3 Transient Heat Transfer in Porous Ducts

Joovey and Dayen (1985) introduced an analytical solution of transient distribution of temperature in a porous bed through which a fluid subjected to a temperature step change at the inlet is flowing. The solution was based on solving two energy balances for both solid and fluid phases (Two-Phase Model). The method developed is suitable for solving higher order partial differential equations resulting from coupled phenomena such as heat interaction or diffusion between several phases with or without sources. Dixon and Cresswell (1986) presented a general theory for the prediction of the effective heat transfer parameters for the transient packed bed models. It was concluded that the effective heat transfer parameters used in the pseudo-homogeneous models of packed bed used in the steady state analysis are different from those used for the transient. In 1988, Dixon determined experimentally the effective radial thermal conductivity and the heat transfer coefficient for a packed bed. The experiments conducted for beds of spheres, full and hollow cylinders for a particle Reynolds number in the range of 100-1000 and d_t/d_p in the range of 5-12. The heat transfer coefficient for a system of Rashig rings was 20-25% higher than that of a system of spherical packing. The radial Peclet number showed a significant dependence on the solid thermal conductivity, gas flow rate and the particle shape while the Biot number showed dependence on the tube to particle diameter ratio, the gas flow rate and the shape of the particles. Bulk (1991) studied the transient heat and mass transfer of a laminar flow forced convection in rectangular packed ducts. He examined the validity of the assumption that the heat and mass transfer coefficients being uniform and constant during the modeling of heat and mass regenerators. He presented a theoretical and experimental study of the variation of the transfer coefficient with time and position of flow passages of regenerative dehumidifiers. The experimental and theoretical analysis showed that heat and mass transfer coefficients vary little with position for the slowly moving mass transfer wave. The results validate the assumption of constant heat and mass transfer coefficients in the modeling process. Borkink et al. (1992) studied the influence of the actual bed structure on the overall heat transfer coefficient, as used in the pseudo-homogeneous model. The bed structure was characterized by a radially averaged and axially varying porosity profile. The porosity profiles were obtained experimentally for spheres, full cylinder and Rashig rings. The change in the bed structure was made by repacking the bed. Al-Nimr et al. (1994) investigated the problem of transient forced convection heat transfer in the entrance region of a cylindrical porous medium with thermally developing boundary layer. The transient is initiated by a step change in the tube wall temperature. They presented a numerical solution using finite difference. The study investigated the effects of the fluid and solid matrix parameters on the Nusselt number, thermal entrance length, total heat absorbed and mixing cup temperature. The study revealed that the mixing cup temperature, the heat absorbed and the Nusselt number will increase as the inertia effect increases. As the porosity decreases, the mean bulk temperature increases. They also found that the inertia effect on the mixing cup temperature would not be significant at low permeability. The thermal entrance length for a higher porosity medium is shorter than that for a lower one. Al-Nimr et al. (1994) introduced a numerical solution for the problem of transient forced convection heat transfer in the entrance region of a porous concentric annulus with developing thermal boundary layer. The hydrodynamic behavior of the flow is assumed steady and fully developed. They investigated the effect of the fluid and solid matrix parameters on the mixing cup temperature, heat absorbed and the Nusselt number. The mixing cup temperature and the Nusselt number increase, as the inertia effect becomes significant. It was found also that decreasing the porosity would cause the Nusselt number and the mixing cup temperature to increase. Alkam and Al-Nimr (1998) studied numerically the transient force convection heat transfer in the developing region of a cylindrical channel partially filled with a porous substrate. They concluded that the presence of the porous substrate improve the Nusselt number (*Nu*) at the fully developed region by a factor of eight. The maximum *Nu* obtained at an optimum porous substrate thickness beyond which no major improvement in *Nu* occurred. The steady state time was noticed to rise with the increase in the substrate thickness to a certain limit then the steady state time decreased with further increase in the thickness of the solid matrix.

2.4 Significance of Axial Heat Dispersion

The axial dispersion of mass and heat in packed ducts has been of great interest for many years. Mchenry and Wilhelm, for their work published in 1957, are considered among the pioneers who studied experimentally the significance of the mass axial dispersion. They showed that the Peclet number for axial dispersion of mass at a fully developed flow equals to two. The axial dispersion of heat gained more interest since 1970. It was shown that the inclusion of the axial dispersion term in the heat equation of a heat transfer in a cooled tubular reactor under reaction conditions could significantly alter the predicted temperature profile (Young and Finlayson, 1973). Borkink and Westerterp (1992) studied numerically the significance of axial heat dispersion for the description of the steady state heat transport in wall-cooled or heated packed beds. They found that the axial dispersion has no significance in heat transfer without a reaction in a wall-cooled or heated packed bed if Reynolds number Re, is grater than 50 and the correct radial inlet temperature profile is used. The axial dispersion of heat is usually neglected from the energy balance equation during the study of steady state heat transfer in packed beds. However, the axial dispersion needs to be considered in the dynamic heat transport process described by a pseudo-homogenous model.

2.5 Velocity Profile

The velocity profile in a packed duct is usually taken as that of a plug flow. However; it was found that the theoretical prediction of the chemical reactor performance was improved by using a non-uniform flow distribution within the packed duct (Kalthoff and Vortmeyer, 1980; Vortmeyer and Winter, 1981). Vortmeyer and Schuster (1983) developed an analytical expression for the velocity profile in a packed duct. The region of high velocity exists within one half the particle diameter from the duct wall. Makkawi (1995) and Abu-Saud (1997) presented the velocity profile for flow in the packed duct by solving numerically the modified Brinkman-Ergun model. They have shown that the velocity profile resembles that of the plug flow model. The predicted velocity profile developed by Abu-Saud (1997) for large sphere is shown in Figure 2.1.

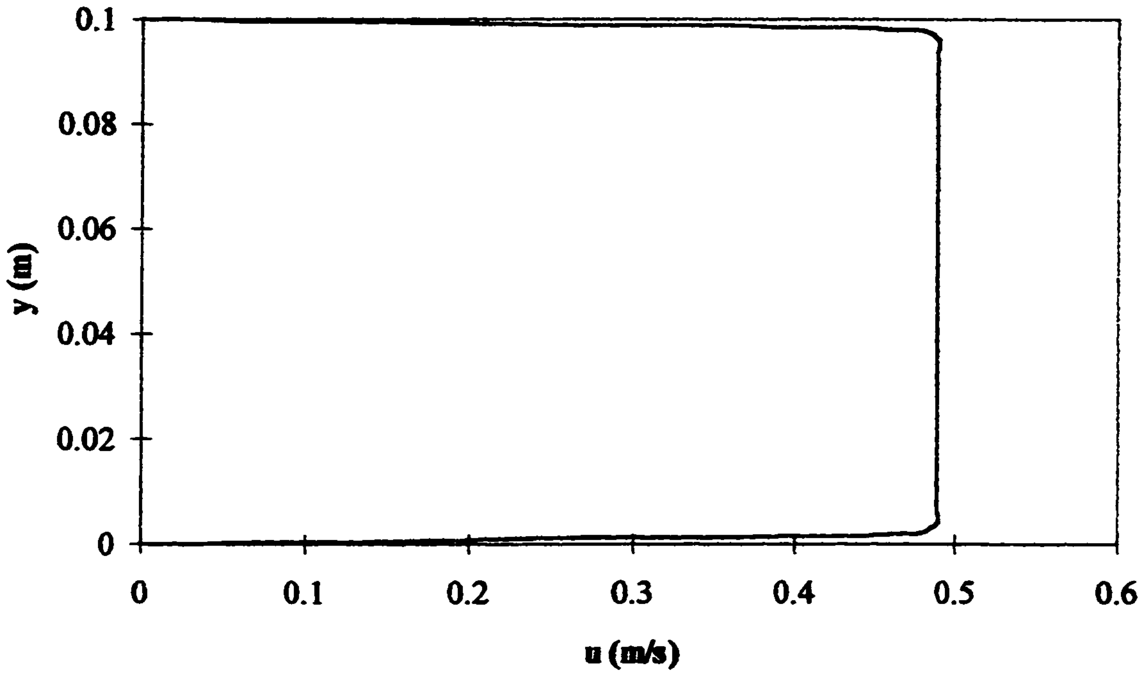


Figure 2.1: Predicted Velocity Profile For a Packed Duct of Polystyrene Sphere; d_p =5.25 cm, (Abu-Saud, 1997).

2.6 Scope and Objectives of the Project:

The objective of this project is to study the transient convection heat transfer experimentally and numerically in a large rectangular packed duct with asymmetric heating. Based on the literature survey, studies of the dynamic behavior of a heat transport in a packed duct are rarely found. Most of the research conducted is focused on studying the steady state heat transfer in both cylindrical and rectangular packed ducts. These studies mainly relate the Nusselt number to Reynolds number and the ratio of the duct equivalent diameter to the particle diameter (d_e/d_p).

Most of the transient heat transfer studies were carried out for empty cylindrical and rectangular geometry, and a limited number for the transient convection heat transfer in packed rectangular ducts. The uniqueness of the present work is to study the transient response of forced convection heat transfer in a large rectangular duct with one-sided heating. The experimental results are used to validate the mathematical one-phase model.

The axial dispersion of heat is usually neglected from the heat equation during the study of steady state heat transfer in packed beds. However, the axial dispersion needs to be considered in the dynamic heat transport process described by a pseudo-homogenous model (Borkink and Westerterp, 1992).

Based on the above, the following objectives are covered:

1. Temperature measurement at different Reynolds number and heat input for various size and shape of packing.
2. Solving numerically the one phase pseudo-homogenous model proposed for the rectangular packed duct with asymmetric heating.
3. Studying the significance of axial dispersion on the transient convection heat transport process in a packed rectangular duct with a heated top wall by a uniform heat flux and insulated bottom wall.
4. The experimental data will be compared with those predicted by a numerical analysis based on the pseudo-homogenous model. The transient response is represented graphically for the local axial and radial temperatures.

CHAPTER 3

EXPERIMENTAL SETUP AND PROCEDURE

3.1 Introduction

The importance of the experimental study of the heat transfer in packed ducts lies on the calculation of the appropriate effective heat transfer parameters. It is also essential to validate the proposed mathematical models representing a certain system. In the present work involving the study of transient convection heat transfer in a large rectangular packed duct with asymmetric heating, the obtained experimental data are utilized to examine the proposed pseudo-homogeneous one phase model. The experimental setup used in this study was initially built for the investigation of steady state behavior of heat transfer in a packed rectangular duct with asymmetric heating. The existing system is utilized with some minor modification.

3.2 Experimental Setup

3.2.1 Apparatus

The experimental apparatus of this study is a rectangular duct, which is 180 cm x 40 cm x 10 cm in dimensions. The duct is divided into three sections. The inlet and the outlet sections which are 10 cm long each and the packing section, which is 160 cm long. The rectangular duct is made of a Perspex material (acrylic sheets). It is well insulated from the surrounding by vermiculite and ceramic fiber insulation. In the inlet and outlet sections, two distributor plates were installed to support the packing and to give uniform distribution of air.

The top plate of the duct is made of galvanized mild steel and it is 1 mm thick. A heating element was installed to provide a uniform heat flux along the airflow passage. A variak was used to supply the adjustable power input to the resistance heater of the heating element. The top section of the duct is removable to allow filling and changing the packing material.

The duct is also provided with 24 K-type thermocouples to measure the temperature at different locations of the duct. Twelve of these thermocouples are dedicated to measure the airflow temperatures. They are located at a distance 30, 63, 96 and 129 cm away from the inlet section and 20, 50, and 80 mm from the top heated plate. Two thermocouples are used to measure the inlet and outlet temperature. Six thermocouples are installed to measure the top wall temperature and the other four thermocouples for measuring the bottom wall temperature. However, due to the limitation of the data acquisition and control system which is capable of accommodating 16 channels only, the bottom wall thermocouple are disconnected and only two thermocouples are utilized to measure the top wall temperature. The location of the different thermocouples is tabulated in Table 3.1. A complete experimental setup is depicted in Figure 3.1.

3.2.2 Packing Materials

The packing material used in this study consists of two packing types; Expanded Polystyrene spheres and Polyvinyl Chloride Plastic (PVC) Raschig rings. The properties of the spherical and Rashig ring packing are given in Tables 3.2 and 3.3 respectively. The complete properties of the two types of packing relative to the duct are indicated in Table 3.4.

Table 3.1 Positions of Thermocouples.

<table>
<tr><td>Top Wall;
Axial Distance (cm)</td><td>25</td><td>47</td><td>69</td><td>91</td><td>113</td><td>135</td></tr>
<tr><td>Inlet Section</td><td colspan="4">Packed Section (x,y) (cm)</td><td colspan="2">Outlet Section</td></tr>
<tr><td rowspan="3">1</td><td>(30,2)</td><td>(63,2)</td><td>(96,2)</td><td>(129,2)</td><td colspan="2" rowspan="3">1</td></tr>
<tr><td>(30,5)</td><td>(63,5)</td><td>(96,5)</td><td>(129,5)</td></tr>
<tr><td>(30,8)</td><td>(63,8)</td><td>(96,8)</td><td>(129,8)</td></tr>
<tr><td>Bottom Wall;
Axial Distance (cm)</td><td>30</td><td>63</td><td>96</td><td colspan="3">129</td></tr>
</table>

Table 3.2 Properties of Spherical Packing.

Size (cm)	Material	Thermal Conductivity (W/m K)	Number of Units
5.25	Expanded Polystyrene	0.037	456
3.87	Expanded Polystyrene	0.037	1260
2.90	Expanded Polystyrene	0.037	3065

Table 3.3 Properties of Rashig Rings.

Outside Diameter (cm)	Inside Diameter (cm)	Height (cm)	Thermal Conductivity (W/m K)	Number of Units
4.82	3.98	4.79	0.14	467
3.36	2.63	3. 23	0.14	1500

Table 3.4 Properties of the packing relative to the duct.

Property	Large Sphere	Medium Sphere	Small Sphere	Large Rashig Ring	Small Rashig Ring	Duct
Material	Expanded Polystyrene (EPS)	Expanded Polystyrene (EPS)	Expanded Polystyrene (EPS)	Polyvinyl Chloride (PVC)	Polyvinyl Chloride (PVC)	Acrylic / Steel / Wood
Outside Diameter (cm)	5.25	3.87	2.9	4.82	3.36	L = 160
Inside Diameter (cm)	-	-	-	3.98	2.63	W = 40
Height (cm)	-	-	-	4.79	3.23	H = 10
Equivalent Diameter (cm)	5.25	3.87	2.9	3.87	3.27	21.69
Density (Kg/m^3)	25	25	25	1422	1422	-
Thermal Conductivity (W/m K)	0.037	0.037	0.037	0.14	0.14	-
Specific Heat (J/kg °C)	1250	1250	1250	825	825	-
Number of Units	456	1260	3065	467	1500	-
Void Fraction	0.460	0.403	0.388	0.797	0.740	-
d_p / d_e	0.242	0.178	0.134	0.178	0.151	-
d_e / d_p	4.131	5.605	7.463	5.605	6.633	-

3.2.3 Instrumentation

i) ***Power Supply Control:***

An auto-variable transformer (110 V-9C 60/HZ) is used to adjust the desired power input to the heating element.

ii) ***Heating Element:***

Thermally high resistance heating wires were used as heating elements. These wires were mounted using galvanized sheet and ceramic connectors. A total of six loops of the heating wires were installed on the galvanized mild steel plate to ensure a uniform distribution of heat along the airflow passage. The arrangement of the heating wires is shown in Figure 3.2.

iii) ***Thermocouple:***

Two different types of thermocouple having an accuracy of ± 0.2 °C were used in this experiment. Quick disconnects thermocouple assembly and the self-adhesive backing K-type thermocouples. The location of each thermocouple is indicated in Table 3.1 and Figure 3.3.

iv) ***Flow Meter:***

The velocity of the fluid air entering the duct was measured using a calibrated Anometer of type HHF710 which has a range of 0.3 to 35.0 m/s. The Anometer has ±1 % accuracy and 0.01 m/s resolution. The air was supplied from the main online compressor through the inlet tube. Two filters were installed in the main supply line to remove any moisture or entrained oil from the incoming air.

v) ***Manometer:***

The pressure drop along the packed duct was measured using a sensitive inclined manometer. The manometer is filled with a merium liquid, which has 0.787 specific gravity at 16°C. The two ends of the manometer were connected to the pressure taps at the inlet and the outlet of the packed duct.

vi) ***Data Acquisition and Control System:***

A system from OMEGA consists of WB-AAI board together with a graphical interface application software, Quicklog PC, which is an icon based program having 20 icons per worksheet was used to log the experimental data. The features of this system are as follows.

1- Measure flow, temperature, pressure and most of the other analog inputs from sensors and instruments.

2- Display and log data to disk for latter analysis.

3- Perform a scale, offset, or complex calculations on a measured variable.

4- Monitor and control processes.

5- Set an alarm limit to any input signal.

6- Control different equipment such as fans, pumps and heaters at a preset level.

7- Control devices from a digital input such as signals from switches.

The system can be used interactively, operating controls and modifying the setup while it is online. The system has 10 input ranges from 25 mV through 10 V and from 1 to 50 mA and it is capable of receiving data from almost any sensor. The high accuracy of the WB-AAI makes it ideal to be used for precise measurement in the laboratory. The system is a user friendly concerning specific engineering units as well as ranges to be used.

vii) ***Personnel Computer (PC):***

A PC which is built by the American Research Corporation (ARC) is interfaced with the Data Acquisition and Control System. The computer is of the type American Megatrend 80286/80287 (ARC 286 BIOS Version 4.1z) with a conventional memory 638K and an extended memory 384K. The PC is occupied with a 40M hard disk.

1. Valve
2. Air filter
3. Flow meter
4. Entrance section
5. Thermocouples
6. Selector switch
7. Inclined manometer
8. Strip heaters
9. Exit section
10. Circuit board
11. Ammeter
12. Voltmeter
13. Rheostat
14. Power supply
15. Data Acquisition and Control

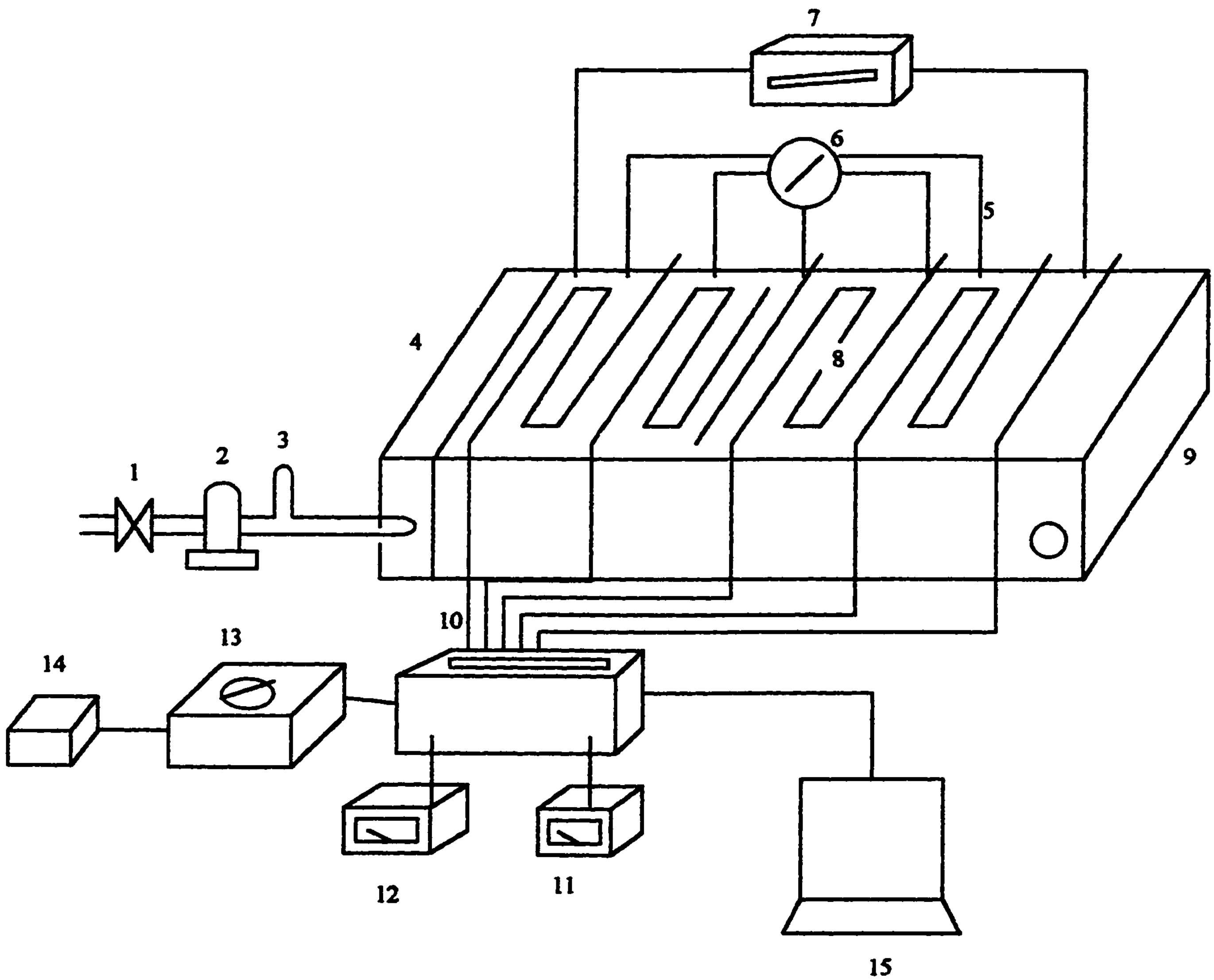


Figure 3.1 Schematic of experimental setup

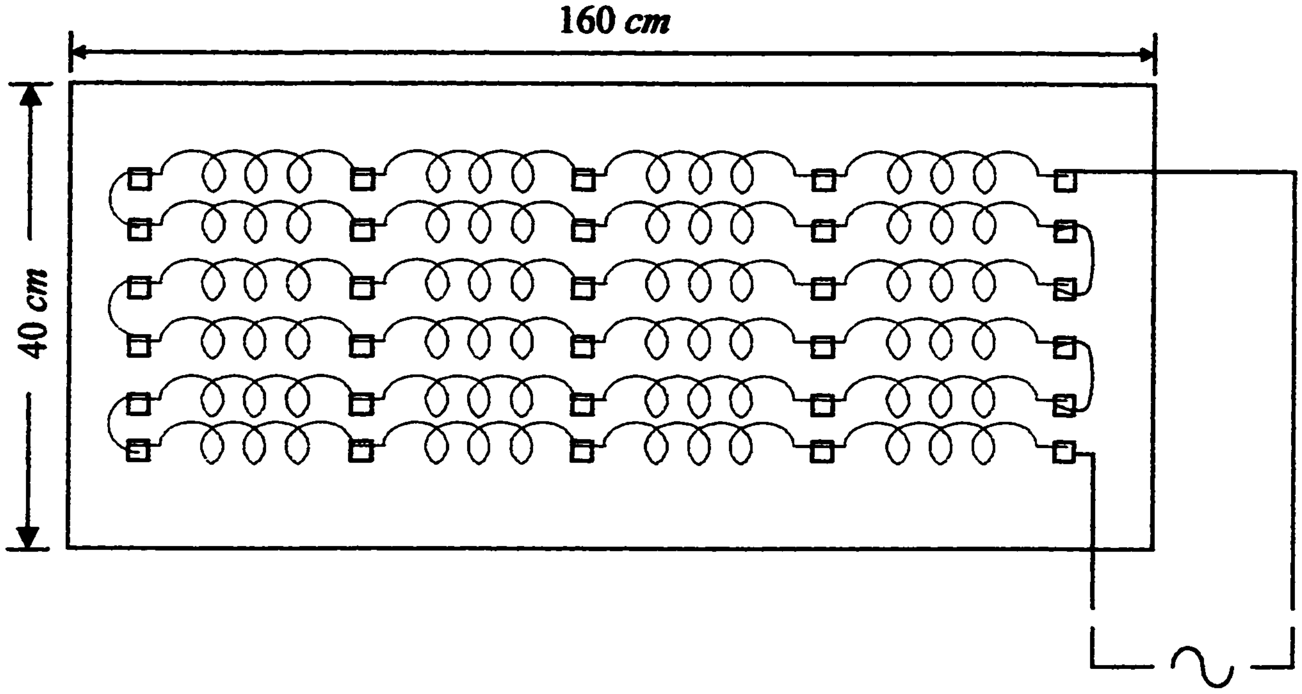
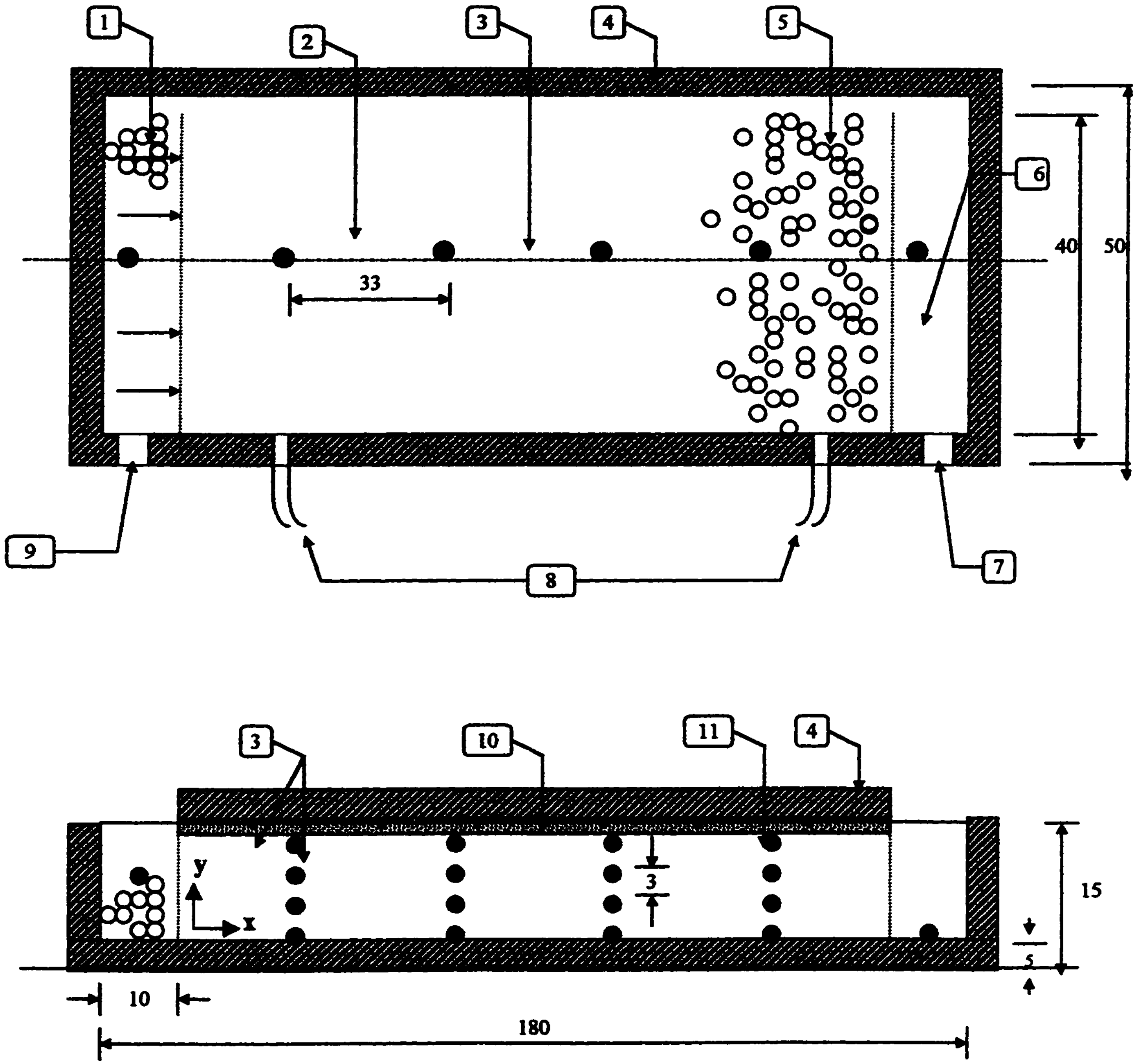


Figure 3.2 Schematic of heating element



1.Inlet section 2. Packed section 3. Thermocouples 4. Insulation 5. Packing 6.Exit section 7. Air outlet 8. Pressure tapping 9. Air inlet 10. Heating element11. Heated plate

Figure 3.3 Schematic of the test section with the positions of thermocouples.

3.3 Experimental Procedure

The duct was filled randomly from the top with the packing material for the specific run. The heat flux as well as the air velocity was set to the required rate. The voltage and amperage out of power control device were measured to calculate the required heat flux. The radial and axial air temperatures inside the packed section of the duct were measured at twelve locations, the inlet and outlet air temperature and the top plate temperature were measured and stored every five minutes. The experimental run would continue until steady state values are reached.

The criterion for reaching the steady state is that when the difference in the measured temperature at various stations is within an accuracy of ± 0.2 °C for thirty minutes. The time to reach steady state conditions differs based on the type of solids and operating conditions. Generally, the time to reach steady state was in the range of 2 to 4 hours. Experimental runs for medium sphere and large Rashig rings (having the same equivalent diameter) at the same heat flux and airflow rate indicated that the time to reach steady state is identical for both packing. Upon reaching the steady state, all logs were stopped and the system was shutdown, left to cool and prepared for the next run. Prior to the startup of the second run, the obtained data were checked and analyzed.

Several runs were done for the various size and shape of packing material. A total of sixty experimental runs were performed for the five different packing materials. A set of twelve runs was done for each packing for four different airflow rates and three different heat inputs. The experimental runs were performed with heat flux in the range of 20 to 243 W/m^2 and a Reynolds number in the range of 300 to 1550. A summary of all experimental runs is indicated in Tables 3.5-3.9.

Table 3.5 Experimental Runs for Small Sphere, $d_p = 2.9$ cm.

Run #	Inlet Temperature (°C)	Velocity (m/sec)	Mass Velocity (Kg/sec)	Mass Flux ($Kg/m^2/sec$)	mC_p (W/°C)	Re	Heat Flux Q_w (W/m^2)	Heat Absorbed Q_a (W/m^2)	Heat Loss Q_L (W/m^2)	% Loss
1	26.2	0.506	0.024	0.595	24.0	935.4	243.4	194.7	48.6	20.0
2	25.6	0.409	0.019	0.481	19.4	756.0	243.4	199.8	43.6	17.9
3	26.6	0.291	0.014	0.343	13.8	538.2	243.4	181.0	62.4	25.6
4	26.8	0.162	0.008	0.190	7.7	299.0	243.4	186.7	56.6	23.3
5	24.8	0.506	0.024	0.595	24.0	935.4	179.2	142.3	36.9	20.6
6	25.5	0.409	0.019	0.481	19.4	756.0	179.2	139.2	40.0	22.3
7	25.5	0.291	0.014	0.343	13.8	538.2	179.2	146.5	32.7	18.2
8	25.5	0.162	0.008	0.190	7.7	299.0	179.2	146.0	33.2	18.5
9	24.6	0.506	0.024	0.595	24.0	935.4	79.4	59.9	19.5	24.5
10	24.5	0.409	0.019	0.481	19.4	756.0	79.4	45.4	34.0	42.8
11	23.9	0.291	0.014	0.343	13.8	538.2	79.4	62.5	16.9	21.3
12	24.6	0.162	0.008	0.190	7.7	299.0	79.4	55.7	23.7	29.9

Table 3.6 Experimental Runs for Medium Sphere, $d_p = 3.87$ cm.

Run #	Inlet Temperature (°C)	Velocity (m/sec)	Mass Velocity (Kg/sec)	Mass Flux (Kg/m²/sec)	mC_p (W/°C)	Re	Heat Flux Q_w (W/m²)	Heat Absorbed Q_a (W/m²)	Heat Loss Q_L (W/m²)	% Loss
1	23.9	0.432	0.020	0.508	20.5	1065.9	179.2	146.8	32.4	18.1
2	23.3	0.357	0.017	0.420	16.9	880.6	179.2	163.0	16.2	9.0
3	23.5	0.273	0.013	0.321	12.9	672.6	179.2	151.5	27.7	15.4
4	23.3	0.181	0.009	0.213	8.6	447.4	179.2	157.9	21.3	11.9
5	23.0	0.432	0.020	0.508	20.5	1065.9	79.4	69.1	10.3	13.0
6	23.7	0.357	0.017	0.420	16.9	880.6	79.4	66.8	12.5	15.8
7	23.8	0.273	0.013	0.321	12.9	672.6	79.4	67.6	11.8	14.8
8	21.6	0.181	0.009	0.213	8.6	447.4	79.4	67.1	12.3	15.4
9	23.3	0.432	0.020	0.508	20.5	1065.9	19.8	9.6	10.3	51.7
10	23.0	0.357	0.017	0.420	16.9	880.6	19.8	11.4	8.5	42.8
11	23.5	0.273	0.013	0.321	12.9	672.6	19.8	17.6	2.3	11.5
12	23.4	0.181	0.009	0.213	8.6	447.4	19.8	14.5	5.3	26.9

Table 3.7 Experimental Runs for large Sphere, $d_p = 5.25$ cm.

Run #	Inlet Temperature (°C)	Velocity (m/sec)	Mass Velocity (Kg/sec)	Mass Flux (Kg/m²/sec)	mC_p (W/°C)	Re	Heat Flux Q_w (W/m²)	Heat Absorbed Q_a (W/m²)	Heat Loss Q_L (W/m²)	% Loss
1	24.6	0.460	0.022	0.541	21.8	1538.8	243.4	186.1	57.2	23.5
2	25.0	0.379	0.018	0.446	17.9	1268.1	243.4	192.4	51.0	20.9
3	24.2	0.282	0.013	0.332	13.4	943.4	243.4	201.9	41.4	17.0
4	24.2	0.189	0.009	0.223	9.0	634.1	243.4	184.5	58.8	24.2
5	24.2	0.460	0.022	0.541	21.8	1538.8	179.2	139.5	39.7	22.1
6	23.3	0.379	0.018	0.446	17.9	1268.1	179.2	157.3	21.9	12.2
7	23.3	0.282	0.013	0.332	13.4	943.4	179.2	148.7	30.4	17.0
8	23.5	0.189	0.009	0.223	9.0	634.1	179.2	134.1	45.1	25.2
9	22.9	0.460	0.022	0.541	21.8	1538.8	79.4	53.1	26.3	33.1
10	23.4	0.379	0.018	0.446	17.9	1268.1	79.4	55.5	23.8	30.0
11	23.2	0.282	0.013	0.332	13.4	943.4	79.4	56.1	23.3	29.3
12	24.4	0.189	0.009	0.223	9.0	634.1	79.4	60.3	19.1	24.0

Table 3.8 Experimental Runs for Small Rashig Ring, $d_p = 3.27$ cm.

Run #	Inlet Temperature (°C)	Velocity (m/sec)	Mass Velocity (Kg/sec)	Mass Flux (Kg/m²/sec)	mC_p (W/°C)	Re	Heat Flux Q_w (W/m²)	Heat Absorbed Q_a (W/m²)	Heat Loss Q_L (W/m²)	% Loss
1	25.3	0.497	0.023	0.585	23.5	1035.5	243.4	181.3	62.1	25.5
2	25.0	0.404	0.019	0.476	19.2	842.8	243.4	203.5	39.9	16.4
3	25.2	0.291	0.014	0.343	13.8	606.8	243.4	213.5	29.8	12.3
4	24.9	0.164	0.008	0.193	7.8	342.0	243.4	180.9	62.5	25.7
5	25.3	0.497	0.023	0.585	23.5	1035.5	179.2	146.0	33.2	18.5
6	25.5	0.404	0.019	0.476	19.2	842.8	179.2	138.3	40.9	22.8
7	27.4	0.291	0.014	0.343	13.8	606.8	179.2	153.0	26.2	14.6
8	26.8	0.164	0.008	0.193	7.8	342.0	179.2	129.1	50.1	28.0
9	26.5	0.497	0.023	0.585	23.5	1035.5	79.4	50.0	29.4	37.0
10	25.2	0.404	0.019	0.476	19.2	842.8	79.4	54.2	25.2	31.8
11	25.8	0.291	0.014	0.343	13.8	606.8	79.4	57.3	22.1	27.8
12	25.2	0.164	0.008	0.193	7.8	342.0	79.4	51.4	28.0	35.3

Table 3.9 Experimental Runs for Large Rashig Ring, $d_p = 3.87$ cm.

Run #	Inlet Temperature (°C)	Velocity (m/sec)	Mass Velocity (Kg/sec)	Mass Flux (Kg/m²/sec)	mC_p (W/°C)	Re	Heat Flux Q_w (W/m²)	Heat Absorbed Q_a (W/m²)	Heat Loss Q_L (W/m²)	% Loss
1	23.8	0.432	0.020	0.508	20.5	1065.9	179.2	130.5	48.7	27.2
2	24.8	0.432	0.020	0.508	20.5	1065.9	79.4	58.8	20.5	25.9
3	24.8	0.357	0.017	0.420	16.9	880.6	79.4	65.8	13.6	17.1
4	25.3	0.357	0.017	0.420	16.9	880.6	179.2	145.3	33.9	18.9
5	25.3	0.357	0.017	0.420	16.9	880.6	19.8	11.6	8.2	41.4
6	25.2	0.432	0.020	0.508	20.5	1065.9	19.8	8.0	11.8	59.7
7	25.0	0.273	0.013	0.321	12.9	672.6	179.2	142.5	36.7	20.5
8	24.7	0.181	0.009	0.213	8.6	447.4	179.2	144.3	34.9	19.5
9	25.3	0.273	0.013	0.321	12.9	672.6	79.4	56.9	22.5	28.3
10	25.5	0.181	0.009	0.213	8.6	447.4	79.4	58.9	20.4	25.8
11	24.8	0.273	0.013	0.321	12.9	672.6	19.8	7.9	12.0	60.3
12	24.1	0.181	0.009	0.213	8.6	447.4	19.8	10.3	9.5	47.9

CHAPTER 4

MATHEMATICAL MODEL

4.1 Introduction

Mathematical modeling of transient heat transfer in a packed rectangular duct is an effective and important tool to represent the dynamic behavior of heat transfer in such system. The model developed would predict data, which would be validated through comparison with those, obtained experimentally for the same heat and flow conditions.

The energy equation for transient forced convection heat transfer in a rectangular packed duct is based on the one phase pseudo-homogeneous model. The pseudo-homogeneous models of transient heat transfer in packed beds have been found by many investigators to give quite adequate results. Dixon and Cresswell (1986) reported that the pseudo-homogeneous model would give a good representation of the dynamic heat transfer if the proper effective heat transfer parameters were used. They also reported that the pseudo-homogeneous model simulations using an effective heat capacity ratio give good results compared with that obtained by a numerical solution of the two-phase model. The use of the two-phase model might be needed in representing a system with very extreme conditions as found by Khanna and Seinfeld (1982), for the highly exothermic methanation reaction.

4.2 Assumptions

The unsteady state model is based on the following assumptions:

1. There is no reaction-taking place in the system.
2. No radiation heat transfer is involved.
3. The pressure drop variation is constant.
4. The airflow in the packed duct is a plug, incompressible flow. The superficial velocity is considered constant across the packed duct.
5. A thermal equilibrium exists between the air and the solid particles.
6. The void fraction across the duct is assumed constant.
7. The physical properties of the fluid air and the solid packing are considered constant and evaluated at the inlet condition.

4.3 Heat Balance Equation

The proposed transient one phase energy balance for the pseudo-homogeneous model is as follows, Dixon and Cresswell (1986).

$$\left[(1-\varepsilon)\rho_s C_s + \varepsilon\rho_f C_f\right]\frac{\partial T}{\partial t} + GC_f\,\frac{\partial T}{\partial x} = k_{ea}\frac{\partial^2 T}{\partial x^2} + k_{ey}\frac{\partial^2 T}{\partial y^2} \quad (4.1)$$

A schematic representation of the coordinate system of the packed duct is given in Figure 4.1.

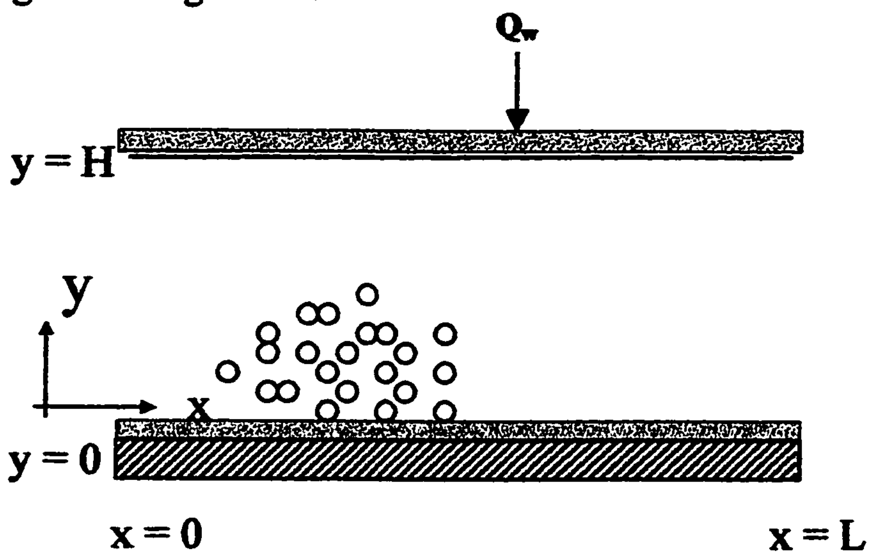


Figure 4.1 Schematic representation of the coordinate system.

Equation (4.1) was solved based on the following initial and boundary conditions.

i) Initial Condition:

Initially the temperature of the fluid air and solid packing is considered constant, uniform and equal to the inlet temperature.

$$t = 0 \qquad T = T_o \tag{4.2}$$

ii) Boundary Conditions:

(1) $x = 0$ $\quad T = T_o$

(2) $x=L$ $\quad \dfrac{\partial T}{\partial x} = \dfrac{q_w w}{\dot{m} C_f}$ (4.3)

(3) $y=0$ $\quad \dfrac{\partial T}{\partial y} = 0$; Well-insulated bottom wall.

(4) $y=H$ $\quad k_{ey} \dfrac{\partial T}{\partial y} = q_w$; Constant heat flux at the top plate.

iii) Derivation of the second Boundary Condition:

The second boundary condition was derived based on the assumption that at infinite distance from the entrance, the system will be thermally fully developed, i.e. the axial temperature gradient is constant.

$\dfrac{dT}{dx} = \dfrac{dT_b}{dx} = \dfrac{dT_w}{dx}$; Convection Heat Transfer, Kays and Crawford (1980).

A heat balance over dx gives:

$$\dot{m}\, C_f dT_b = q_w w dx$$

$$\frac{dT_b}{dx} = \frac{q_w w}{\dot{m} C_f}$$

This leads to the second boundary condition

$$\frac{dT}{dx} = \frac{q_w w}{\dot{m} C_f}$$

Multiply and divide the first term in equation (4.1) by $[(1-\varepsilon)\rho_s C_s]$

$$[(1-\varepsilon)\rho_s C_s + \varepsilon\rho_f C_f]\frac{[(1-\varepsilon)\rho_s C_s]}{[(1-\varepsilon)\rho_s C_s]}\frac{\partial T}{\partial t} + GC_f \frac{\partial T}{\partial x} = k_{ex}\frac{\partial^2 T}{\partial x^2} + k_{ey}\frac{\partial^2 T}{\partial y^2} \tag{4.4}$$

Define the heat capacity ratio (C)

$$C = \frac{[\varepsilon\rho_f C_f]}{[(1-\varepsilon)\rho_s C_s]} \tag{4.5}$$

Substitute in equation (4.4)

$$[1+C][(1-\varepsilon)\rho_s C_s]\frac{\partial T}{\partial t} + GC_f \frac{\partial T}{\partial x} = k_{ex}\frac{\partial^2 T}{\partial x^2} + k_{ey}\frac{\partial^2 T}{\partial y^2} \tag{4.6}$$

Divide equation (4.6) by GC_f and multiply by d_p

$$[1+C]\frac{[(1-\varepsilon)\rho_s C_s]d_p}{GC_f}\frac{\partial T}{\partial t}+d_p\frac{\partial T}{\partial x}=\frac{k_{ea}d_p}{GC_f}\frac{\partial^2 T}{\partial x^2}+\frac{k_{ey}d_p}{GC_f}\frac{\partial^2 T}{\partial y^2} \tag{4.7}$$

4.4 Transformation in a Dimensionless Form

Equation (4.7) was rendered dimensionless by using the following dimensionless groups:

$$\theta = \frac{T - T_R}{T_o - T_R} \tag{4.8a}$$

$$\xi = \frac{x}{L} \tag{4.8b}$$

$$\eta = \frac{y}{H} \tag{4.8c}$$

$$\tau = \frac{tGC_f}{[d_p(1-\varepsilon)\rho_s C_s]} \tag{4.8d}$$

Multiplying the axial and radial dispersion terms in equation (4.7) by (d_p/d_p) and substituting with the dimensionless groups defined above. The heat equation in dimensionless form is as follows:

$$[1+C]\frac{\partial\theta}{\partial\tau}+\frac{d_p}{L}\frac{\partial\theta}{\partial\xi}=\frac{k_{ea}d_p}{GC_fL^2}\left(\frac{d_p}{d_p}\right)\frac{\partial^2\theta}{\partial\xi^2}+\frac{k_{ey}d_p}{GC_fH^2}\left(\frac{d_p}{d_p}\right)\frac{\partial^2\theta}{\partial\eta^2} \tag{4.9}$$

Define the axial and radial effective Peclet numbers and the aspect ratios Pe_a, Pe_y, α_x, α_y respectively as:

$$Pe_a=\frac{GC_fd_p}{k_{ea}} \tag{4.10a}$$

$$Pe_y=\frac{GC_fd_p}{k_{ey}} \tag{4.10b}$$

$$\alpha_x=\frac{d_p}{L} \tag{4.10c}$$

$$\alpha_y=\frac{d_p}{H} \tag{4.10d}$$

The final heat equation in a dimensionless form is:

$$\left[1 + C\right]\frac{\partial\theta}{\partial\tau} + \alpha_x \frac{\partial\theta}{\partial\xi} = \frac{\alpha_x^2}{Pe_a}\frac{\partial^2\theta}{\partial\xi^2} + \frac{\alpha_y{}^2}{Pe_y}\frac{\partial^2\theta}{\partial\eta^2} \tag{4.11}$$

The initial and boundary conditions in dimensionless form are as follows.

i) Initial Condition

$$\tau = 0 \qquad\qquad \theta = 1.0 \tag{4.12}$$

ii) Boundary Conditions

(1) $\xi = 0$ $\qquad$ $\theta = 1.0$ $\qquad$ (4.13a)

(2) $\xi = 1.0$ $\qquad$ $\dfrac{\partial\theta}{\partial\xi} = \dfrac{q_w w L}{\dot{m} C_f (T_o - T_R)}$ $\qquad$ (4.13b)

(3) $\eta = 0$ $\qquad$ $\dfrac{\partial\theta}{\partial\eta} = 0$ $\qquad$ (4.13c)

(4) $\eta = 1.0$ $\qquad$ $\dfrac{\partial\theta}{\partial\eta} = \dfrac{Hq_w}{(T_o - T_R)k_{ey}}$ $\qquad$ (4.13d)

4.5 Effective Radial and Axial Thermal Conductivities.

i) Effective Radial Thermal Conductivity

The effective radial thermal conductivity is calculated based on the relation developed by Zehner and Schlunder (1973).

$$k_{ey} = k_{st} + k_{dy} \tag{4.14}$$

In which, (k_{st}) is the stagnant thermal conductivity defined as the contribution to heat transfer in the packed duct due to the conduction in case of stagnant fluid and it is given by the following relations.

$$\frac{k_{st}}{k_f} = 0.67\varepsilon_i + A\sqrt{(1-\varepsilon_i)} \tag{4.15}$$

$$A = \frac{2}{1-M}\left[\frac{B-M}{(1-M)^2}\ln\left(\frac{1}{M}\right) - \frac{B+1}{2} - \frac{B-1}{1-M}\right]$$

$$M = B\frac{k_f}{k_s}$$

$$B = \hat{C}\left(\frac{1-\varepsilon_i}{\varepsilon_i}\right)^{1.1}$$

$\hat{C} = 1.25$ For spheres and

$\hat{C} = 2.5$ For cylinders and Raschig rings.

The dynamic contribution to heat transfer (k_{dy}) due to fluid flow is defined by the following relations.

$$\frac{k_{dy}}{k_f} = \frac{\varepsilon_i}{\varepsilon_b} \frac{Pe_p^s}{8\left[2 - \left(1 - \frac{2}{N_i}\right)^2\right]} \tag{4.16}$$

$$Pe_p^s = Re_p^s \, Pr = \frac{G d_p C_f}{k_f}$$

It should be noted that in equation (4.16), the local bed porosity ε_i and average bed porosity ε_b are assumed equal and the ratio $\frac{\varepsilon_i}{\varepsilon_b}$ is unity.

ii) Effective Axial Thermal Conductivity:

The effective axial thermal conductivity is calculated based on the relation developed by Dixon, 1979.

$$\frac{1}{Pe_a} = \frac{1}{Pe(\infty)_{af}} + \frac{k_{as}/k_f}{Re\,Pr\left[1 + \frac{1}{N_s}\left(\frac{8Bi_s}{Bi_s + 4}\right)\right]^2} \tag{4.17}$$

Where:

$Pe(\infty)_{af} = 0.5$; limiting value of Pe as $Re \rightarrow \infty$

$k_{as} = k_{rs}$; Stagnant bed thermal conductivities presented by Zehner and Schlunder (1970), equation (4.15).

Bi_s is the solid/wall Biot number and it is defined as:

$$Bi_s = 2.12\left(\frac{d_e/2}{d_p}\right) \tag{4.18}$$

N_s is the interphase heat transfer group and it is given by the following relation.

$$N_s = \frac{1.5(1-\varepsilon)(d_e/d_p)^2}{\left(\frac{k_{rs}}{k_f}\right)\left\{\frac{1}{Nu_{fs}} + \frac{0.1}{k_s/k_f}\right\}} \tag{4.19}$$

The fluid/solid Nusselt number Nu_{fs} is defined for Re > 100 by the following relation.

$$Nu_{fs} = \frac{0.255}{\varepsilon} Pr^{1/3} Re^{2/3} \tag{4.20}$$

The Reynolds number in the equations above is defined based on the particle diameter and it is as follows.

$$Re = \frac{Gd_p}{\mu} \tag{4.21}$$

4.6 Parameter Definition

Some of the important parameters that are used very frequent in the scope of study of transient heat transfer in packed ducts need to be defined. These parameters include the bed void fraction (porosity), equivalent diameter of both the solid particle and the packed duct and also the modified Reynolds number.

4.6.1 Packed Bed Porosity

The void fraction of a packed bed is defined as the ratio of the empty volume present for the fluid to flow through to the total volume of the bed. The following relation defines it.

$$\varepsilon = \frac{\text{Total volume of the duct - Total volume of packing}}{\text{Total volume of the duct}}$$

The total volume of the duct was calculated based on the actual dimensions of the packed duct and the volume of the packing was based on the particle diameter and the total number of each kind of the packing material. The following is a sample calculation for two different types of packing.

i) Large sphere:

Particle diameter; $d_p = 5.25$ cm.

Total number of packing; N = 456

Total volume of the packing material $= \dfrac{4\pi}{3}\left(\dfrac{d_p}{2}\right)^3 * N = 34549.5\ \text{cm}^3$.

Total volume of the duct = 160 * 40 * 10 = 64000 cm^3.

$$\varepsilon = \frac{64000 - 34549.5}{64000} = 0.460$$

ii) Large Rashig Ring:

Outside diameter of particle; $d_{p_o} = 4.82$ cm

Inside diameter of particle; $d_{p_i} = 3.98$ cm

Height of particle; $h_p = 4.79$ cm

Total number of packing; N = 467

Total volume of packing material $= \dfrac{\pi}{4}\left(d_{p_o}^2 - d_{p_i}^2\right) h_p * N = 12986.9\ \text{cm}^3$.

Total volume of the duct = 160 * 40 * 10 = 64000 cm^3.

$$\varepsilon = \frac{64000 - 12986.9}{64000} = 0.797$$

The porosity of the different type of packing is tabulated in Table 3.4.

4.6.2 Equivalent Diameter of Packed Duct

The equivalent diameter for a rectangular channel having an aspect ratio W/H > 3 was given by Normand, 1948 in the following relation.

$$d_e = \left(2.55\,K \frac{(WH)^2}{W + H} \right)^{1/3} \tag{4.22}$$

Where K is a constant having an approximate value of 1.25 for rectangular ducts with aspect ratio of 4, Perry 1985.

The value of the equivalent diameter of our experimental duct was calculated and it is equal to 21.69 cm.

4.6.3 Equivalent Diameter of Packing

The equivalent diameter of non-spherical packing is given by the following relations (McCabe et. al, 1985).

$$d_p = \frac{6(1-\varepsilon)}{\phi_s a_p} \tag{4.23}$$

Where:

ϕ_s is the shape factor and it equals 0.3 for the Rashig ring.

a_p is the surface area of the solid particle per unit volume of the bed and it is defined by the following relation.

$$a_p = \frac{N\left[\left(\pi d_{p_o} d_{p_o} + \pi d_{p_i} d_{p_o}\right) + \pi\left(d_{p_o}^2 - d_{p_i}^2\right)/4\right]}{LWH} \tag{4.24}$$

Where:

N is the total number of the solid particle.

L, W, H, are the dimensions of the rectangular duct.

d_{p_o}, d_{p_i} are the outside and inside diameter of the particle respectively.

4.6.4 Modified Reynolds Number

The effect of the porosity is always considered in the calculation of the Reynolds number in a packed duct. The modified Reynolds number in a packed duct is given by the following relation; Denn (1980).

$$Re_p = \frac{\rho \upsilon_\infty d_p}{(1-\varepsilon)\mu} \tag{4.25}$$

Where:

υ_∞ is the superficial velocity of fluid air inside the packed duct.

4.7 Solution Method

The proposed energy equation for the transient heat transfer in a rectangular packed duct with asymmetric heating, and its boundary conditions were solved numerically using the method of Orthogonal Collocation. This method is summarized below.

4.7.1 Orthogonal Collocation Method

Any two nonzero functions $P_n(x)$ and $P_m(x)$ are said to be orthogonal on the interval $a \le x \le b$ with respect to the weight function $w(x)$ if their scalar product vanishes.

$$\int_a^b w(x)P_n(x)P_m(x)dx = 0 \qquad n \ne m \tag{4.26}$$

A further extension of the method is choosing collocation points as roots of the orthogonal polynomials. If the upper condition is satisfied then the polynomial $P_n(x)$ is orthogonal over the domain [a, b]. The basis of the collocation method is to assume a trial function which will satisfy the boundary conditions exactly or in some average sense.

There are two polynomial forms that are often used to solve engineering problems. These are the Shifted Legendre polynomials and the Jacobi polynomials. The Shifted Legendre polynomials are used for problems without symmetry and the Jacopi polynomials are used for problems with symmetry. Since our heat problem is not symmetrical, the Shifted Legendre polynomials were chosen. The total number of the collocation points was selected to be eighteen points plus two boundary points in the axial direction and nine points plus two boundaries in the radial direction (y-direction). These points represent the roots of the Shifted Legendre polynomials. A computer program was used to generate those roots and they are as follows.

i) Axial Legendre Collocation Points

The collocation points in the axial direction were generated for eighteen interior nodes and two boundary conditions and they are listed in Table 4.1.

Table 4.1 Axial Collocation points

ξ (1)= 0.0000	ξ (6)= 0.1542	ξ (11)= 0.5424	ξ (16)= 0.9019
ξ (2)= 0.0042	ξ (7)= 0.2201	ξ (12)= 0.6259	ξ (17)= 0.9463
ξ (3)= 0.0221	ξ (8)= 0.2941	ξ (13)= 0.7059	ξ (18)= 0.9779
ξ (4)= 0.0537	ξ (9)= 0.3741	ξ (14)= 0.7799	ξ (19)= 0.9958
ξ (5)= 0.0981	ξ (10)= 0.4576	ξ (15)= 0.8458	ξ (20)= 1.0000

ii) Radial Legendre Collocation Points

The collocation points in the radial direction were found for nine interior nodes plus two boundary conditions and they are listed in Table 4.2.

Table 4.2 Radial Collocation points

$\eta\,(1) = 0.0000$	$\eta\,(4) = 0.1933$	$\eta\,(7) = 0.6621$	$\eta\,(10) = 0.9841$
$\eta\,(2) = 0.0159$	$\eta\,(5) = 0.3379$	$\eta\,(8) = 0.8067$	$\eta\,(11) = 1.0000$
$\eta\,(3) = 0.0820$	$\eta\,(6) = 0.5000$	$\eta\,(9) = 0.9180$	

4.7.2 The Shifted Legendre Polynomials

In the Shifted Legendre problem we consider the spatial domain ξ and η in the range $[0,1]$ and that the problem has no symmetry properties over that domain. The spatial term in the differential equation is converted into a polynomial of the following forms.

The first derivatives are approximated by:

$$\frac{\partial\theta_{ij}}{\partial\xi} = \sum_{k=1}^{N+2} Ax_{ik}\theta_{kj} \tag{4.27}$$

$$\frac{\partial\theta_{ij}}{\partial\eta} = \sum_{k=1}^{M+2} Ay_{jk}\theta_{ik} \tag{4.28}$$

The second derivatives are approximated by:

$$\frac{\partial^2\theta_{ij}}{\partial\xi^2} = \sum_{k=1}^{N+2} Bx_{ik}\theta_{kj} \tag{4.29}$$

$$\frac{\partial^2\theta_{ij}}{\partial\eta^2}=\sum_{k=1}^{M+2}By_{jk}\theta_{ik} \tag{4.30}$$

Where:

$N = 18$ and $M = 9$ are the number of the collocation points in the axial and radial direction respectively.

Ax_{ik}, Ay_{jk}, Bx_{ik} and By_{jk} are the first and the second derivative matrix parameters for the Shifted Legendre polynomials in the axial and radial direction respectively. The values of these parameters are listed in Tables B1.1-B2.2 of appendix B.

According to the orthogonal collocation method and for a two-dimensional problem, the number of the Shifted Legendre polynomials should be (N+2) x (M+2); i.e. 220 polynomials. However, since the conditions are known at the boundaries, we end up having 168 polynomials representing the derivatives. The two-dimensional problem was rendered one-dimensional by defining the temperature vector indicated in Table B3.1 of appendix B.

The heat equation (4.11) was rearranged to the following.

$$\frac{\partial\theta}{\partial\tau}=\frac{\alpha_x^2}{[1+C]Pe_x}\frac{\partial^2\theta}{\partial\xi^2}+\frac{\alpha_y^2}{[1+C]Pe_y}\frac{\partial^2\theta}{\partial\eta^2}-\frac{\alpha_x}{[1+C]}\frac{\partial\theta}{\partial\xi} \tag{4.31}$$

Substituting for the first and second derivatives defined in equations (4.27-4.30).

$$\frac{\partial\theta_{ij}}{\partial\tau}=\frac{\alpha_x^2}{[1+C]Pe_a}\sum_{k=1}^{N+2}Bx_{ik}\theta_{kj}+\frac{\alpha_y^{\,2}}{[1+C]Pe_y}\sum_{k=1}^{M+2}By_{jk}\theta_{ik}-\frac{\alpha_x}{[1+C]}\sum_{k=1}^{N+2}Ax_{ik}\theta_{kj}$$

By defining the following variables.

$$\text{ZPRIME }(I)=\frac{\partial\theta_{ij}}{\partial\tau}$$

$$F_1=\frac{\alpha_y^2}{[1+C]Pe_y}$$

$$F_2=\frac{\alpha_x^2}{[1+C]Pe_a}$$

$$F_3=\frac{\alpha_x}{[1+C]}$$

The final form of the polynomials is as follows.

$$\text{ZPRIME }(I)=F_1\sum_{k=1}^{M+2}By_{jk}\theta_{ik}+F_2\sum_{k=1}^{N+2}Bx_{ik}\theta_{kj}-F_3\sum_{k=1}^{N+2}Ax_{ik}\theta_{kj}\qquad(4.32)$$

The series in equation (4.32) were expanded and the equation was written for all interior nodes giving 162 polynomials.

The boundary conditions represented by equation (4.13) were also written in terms of polynomials and they are as follows.

(1) $\xi = 0$ $\qquad\qquad \theta_{1,j} = 1.0$ (4.33a)

(2) $\xi = 1.0$ $\qquad\qquad \dfrac{\partial\theta_{1,j}}{\partial\xi} = \sum_{k=1}^{N+2} Ax_{1,k}\theta_{k,j} = \dfrac{q_w w L}{\dot{m} C_f (T_o - T_R)} = F_4$ (4.33b)

(3) $\eta = 0$ $\qquad\qquad \dfrac{\partial\theta_{i,1}}{\partial\eta} = \sum_{k=1}^{M+2} Ay_{1,k}\theta_{i,k} = 0$ (4.33c)

(4) $\eta = 1.0$ $\qquad\qquad \dfrac{\partial\theta_{i,11}}{\partial\eta} = \sum_{k=1}^{M+2} Ay_{11,k}\theta_{i,k} = \dfrac{Hq_w}{(T_o - T_R)k_{ey}} = Q$ (4.33d)

The series for the 58 nodes at the boundaries were expanded and the polynomial for these nodes were written. A total of 220 polynomials representing the interior nodes as well as the nodes of the boundaries were solved by a computer program supplemented by some IMSL subroutines. The computer program and the expanded polynomials are listed in appendix B.

CHAPTER 5

RESULTS AND DISCUSSION

5.1 Introduction

The intention of the present work is to study the transient behavior of forced convection heat transfer in a rectangular packed duct with asymmetric heating. The scope of the study involves an experimental work and a mathematical modeling of the problem. A complete description of the experimental setup and procedure is given in chapter 3 of this thesis. The development of the mathematical model and its boundary conditions is presented in chapter 4. The experimental work involved the measurement of the air temperature at twelve different stations along the packed section of the testing apparatus. Two types of packing, expanded polystyrene spheres and polyvinyl chloride Rashig Rings were used in the experiments. A total of sixty experimental runs were performed for all five packing materials with heat flux in the range of 20 to 243 W/m^2 and Reynolds number in the range of 300 to 1550. The measured data were compared with those predicted by the mathematical model. The effect of shape and size of packing on the time needed to reach steady state was studied. The air temperature trends at different Reynolds number for the same packing were compared to show the effect of the airflow rate on the time required to reach steady state. The significance of the axial dispersion on the transient convection heat transfer on a packed duct with asymmetric heating was also analyzed.

5.2 Analysis of Mathematical Model Results

The mathematical modeling of the transient convection heat transfer in packed duct with asymmetric heating was based on the pseudo-homogeneous model. The pseudo homogeneous one phase model has no discrepancy between the temperature of the solid and fluid phases. The problem was solved initially with the Peaceman Rachford Alternating-Direction Implicit Finite Difference method. This method encountered an oscillation problem. The output jumps to a maximum and start oscillating until steady state is reached. However, this method gave a good prediction of the temperature for a system packed with heavy packing material such as glass beads or steal balls. Finally, the model was solved numerically with the method of orthogonal collocation. The numerical output of the problem was very sensitive to the time increment used in the program. Several time increments were used and the best was a time increment of one minute.

The heat input at the top wall is a combination of the heat absorbed by the air and the solid plus that dissipated to the surrounding. However the heat dissipated to the environment can be neglected because the experimental setup is very well insulated. The heat flux used in the program was the flux calculated based on the amount of heat absorbed by the flowing air at steady state. The amount of heat absorbed by the solid was considered as a loss. The heat absorbed by the air and that lost to heat the solid are calculated for the different experimental runs and they are listed in Tables 3.5-3.9.

The predicted data was compared with those measured experimentally and showed a satisfactory agreement. The comparison was done for the axial and radial air temperature trend relative to time for the five different types of packing. A schematic representation of the assessment is depicted in Figures 5.1-5.55. Figures 5.1-5.11 represent the measured and predicted radial and axial temperatures for a system packed with large expanded polystyrene spheres for Reynolds number of 1268 and a heat flux of 243.4 W/m^2. From these figures it can be seen that the predicted temperature is in a good compliance with those measured experimentally. Figure 5.1 indicates that a maximum deviation of 4 % in the air temperature occurred at 30 cm from the entrance of the duct and 8 cm close to the top wall where a constant heat flux is supplied. The deviation might be attributed to the non-equilibrium state which is not established yet between the solid and the fluid air in addition to the error in the measurement. Figure 5.4 for the radial temperatures at 129 cm from the entrance indicates that as the airflow reaches the end of the packed section, the measured and predicted air temperatures are almost identical with considerable low deviation. These uniform temperatures can be attributed to the real equilibrium state which is reached between the solid and the fluid phases.

The measured and predicted radial and axial temperature trends for a system packed with medium spheres for Reynolds number of 671.7 and heat flux of 79.4 W/m^2 are indicated in Figures 5.12-5.22. Figure 5.18 for the axial air temperature trend at 8 cm close to the heated wall indicates that a maximum deviation of 2.5 % was observed on the air temperature predicted at 30 cm away from the entrance. The temperature trends for the system packed with small spheres for Reynolds number of 756 and a heat flux of 243.4 W/m^2 are shown in Figures 5.23-5.33. A maximum deviation of 3.7 % was also observed at the same axial distance from the entrance.

Figures 5.34-5.44 represent the air temperature trends for the system packed with polyvinyl chloride large Rashig Rings at Reynolds number of 669 and a heat flux of 179.2 W/m^2. Figure 5.34 for the radial temperature trend at 30 cm from entrance indicates that a maximum deviation of 5.5 % between the measured and predicted air temperature is present close to the heated wall. The temperature trends for the system packed with small Rashig

Ring for Reynolds number of 606.8 and a heat flux of 179.2 W/m^2 are shown in Figures 5.45-5.55. A maximum deviation of 8 % was observed close to entrance.

Tables 5.1 and 5.2 present the percentage error between the measured and predicted temperature for a large sphere and small Rashig Ring. A maximum percentage deviation of 8 % occurs at 30 cm away from the inlet and close to the top wall. The error may be due to the non-equilibrium state between the solid and the fluid phases and due to experimental errors.

The measured and predicted axial air temperatures of the five different packing are shown in Figures 5.56-5.60. These figures indicate that the axial temperature gradient close to the exit of the packed section is constant. This validates the use of the second boundary condition, equation 4.3.

5.3 Effect of Shape and Size of Packing on Heat Transfer

The effect of shape of packing on the time required to reach steady state was studied. Several experimental runs were done for medium sphere and large Rashig Ring having the same equivalent diameter with the same heat flux and the same airflow rate. The measured and predicted axial temperature trends for both packing are schematically represented in Figures 5.61-5.64.

These figures have shown that shape of packing has neither influence on the time needed to reach steady state nor the air temperature.

The effect of the packing size on the transient heat transfer was also studied for different particles. Figures 5.65-5.69 for the measured and predicted axial temperature trend indicates that the time required to reach steady state is not affected by the packing size. However, the temperature has shown a slight improvement when smaller particles are used. It can be concluded that the smaller particles create more mixing effect and hence improve the heat transfer. The conclusion drawn from the predicted temperature trend is in compliance with that drawn from the measured one. Figure 5.70 correlate the pressure drop to the shape and size of packing for different airflow rate. This figure indicated that Rashig Ring has less pressure drop compared with that of spherical packing.

5.4 Effect of Reynolds Number on Heat Transfer

One of the parameters affecting the heat transfer in packed duct is the fluid flow rate. In this experimental and theoretical study, the effect of Reynolds number on the transient heat transfer was considered. Figures 5.71-5.74 for the measured and predicted air temperatures reflect the dependency of heat transfer and time required to reach steady state on Reynolds number.

These figures indicated that the transient heat transfer is inversely proportional to Reynolds number. As the airflow decreases, both the air temperature and the time needed to reach steady state increase. The inverse proportionality in the transient heat transfer is explained by the fact that the residence time of the air increases as the air flow rate decreases. The verdict reached from the predicted as well as the measured temperature trends is the same.

5.5 Significance of Axial Dispersion

The study of the significance of axial dispersion on heat transfer in packed ducts is a very wide study and requires a massive work. One of the objectives of this project is to emphasize the importance of axial dispersion on the transient convection heat transfer in a rectangular packed duct with asymmetric heating. Tables 5.3 and 5.5 tabulate the values of radial and axial dispersions at different locations of the experimental rectangular packed duct for medium spheres and large Rashig Ring respectively. Figures 5.75-5.76 represent the significance of axial dispersion in a system packed with medium sphere with Reynolds number of 1067 and a heat flux of 179.2 W/m^2. These figures indicate that the ratio of axial dispersion to radial dispersion decreases as the steady state is reached. It can be concluded that the axial dispersion is more significant at the early time compared with that at steady state.

Tables 5.4 -5.6 tabulates the values of the axial and radial dispersions for a system packed with large Rashig Rings at three different Reynolds numbers. The ratio of axial dispersion to radial dispersion versus Reynolds number is represented graphically in Figures 5.77-5.78. These figures indicate that the ratio decreases with the decrease in Reynolds number, which reflects that the significance of axial dispersion is highly affected by Reynolds number. A consequence of the above, axial dispersion can be neglected when modeling a system with a very low Reynolds number.

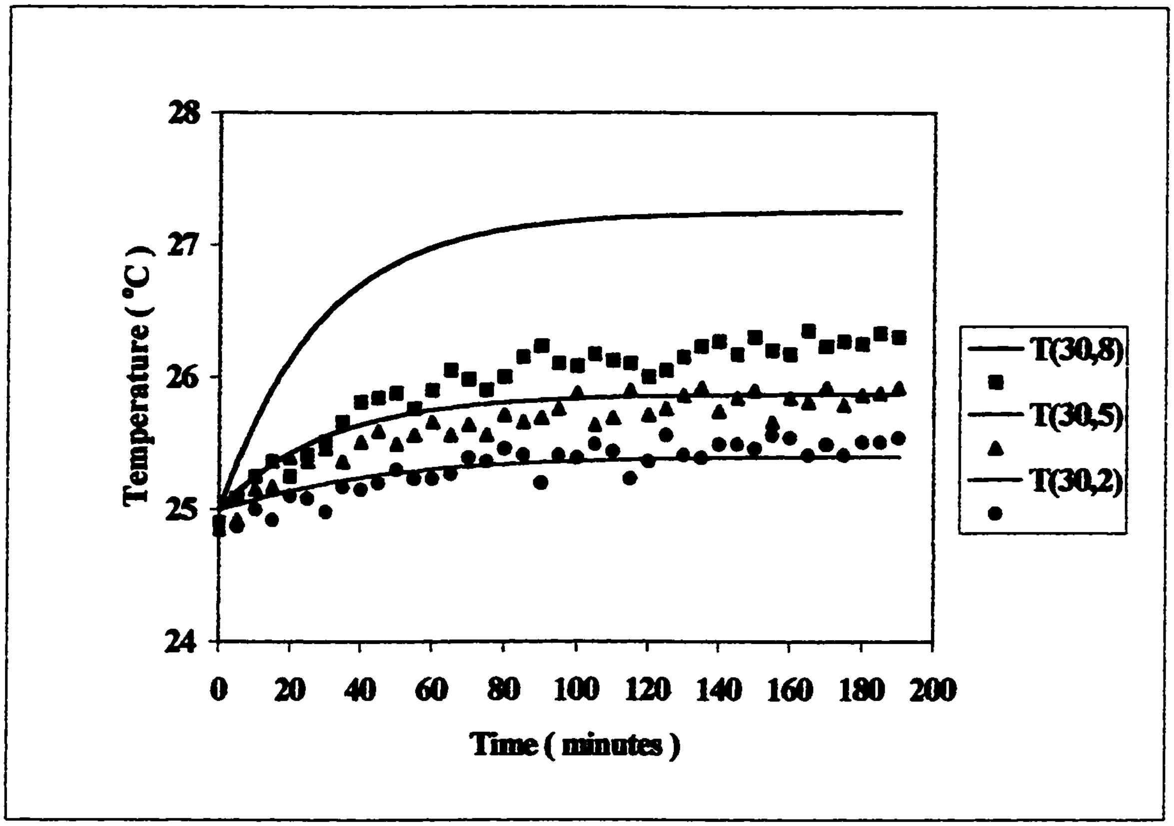


Figure 5.1: Measured and Predicted Radial Temperature Trend for Large Sphere, d_p =5.25 cm, Run # 2 at x = 30 cm, Re = 1268.1, Q_w = 243.4 W/m^2.

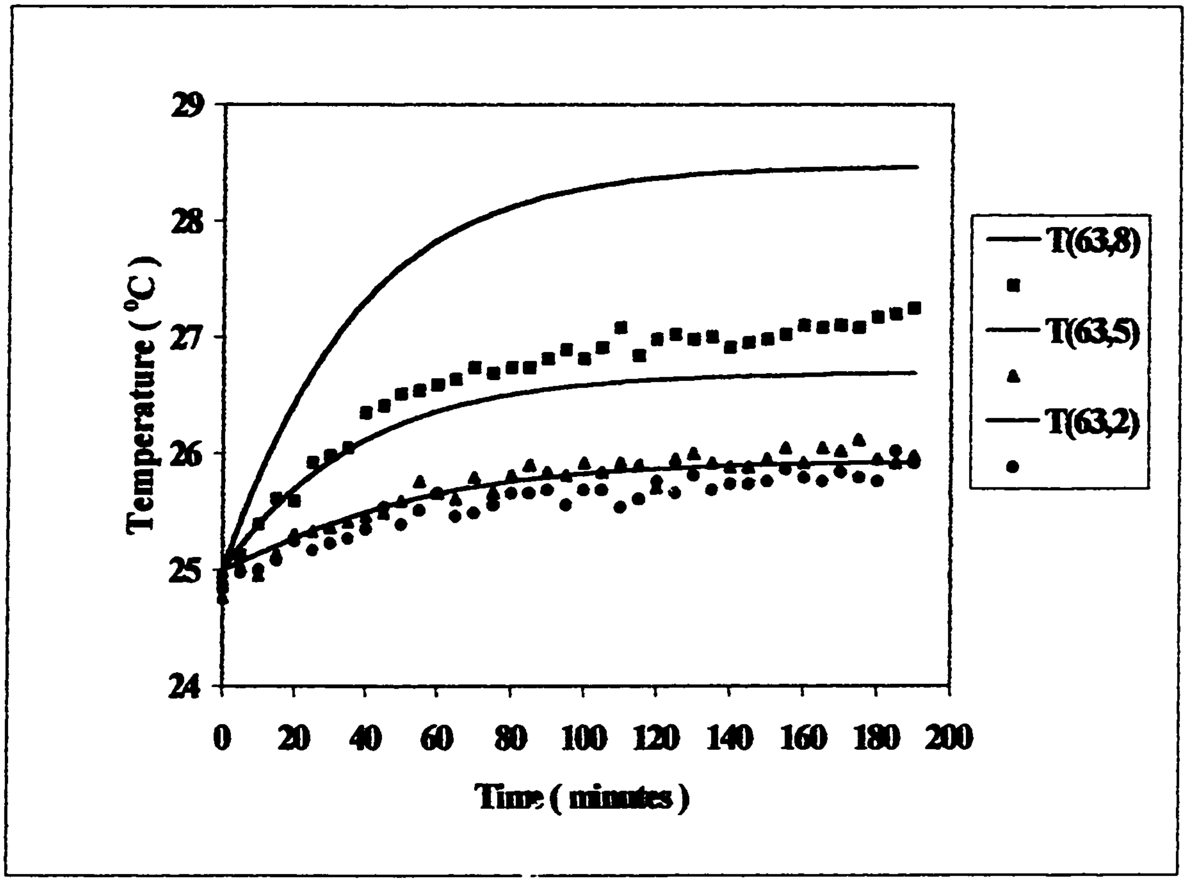


Figure 5.2: Measured and Predicted Radial Temperature Trend for Large Sphere, d_p =5.25 cm Run # 2 at x = 63 cm Re = 1268.1 Q_w = 243.4 W/m^2.

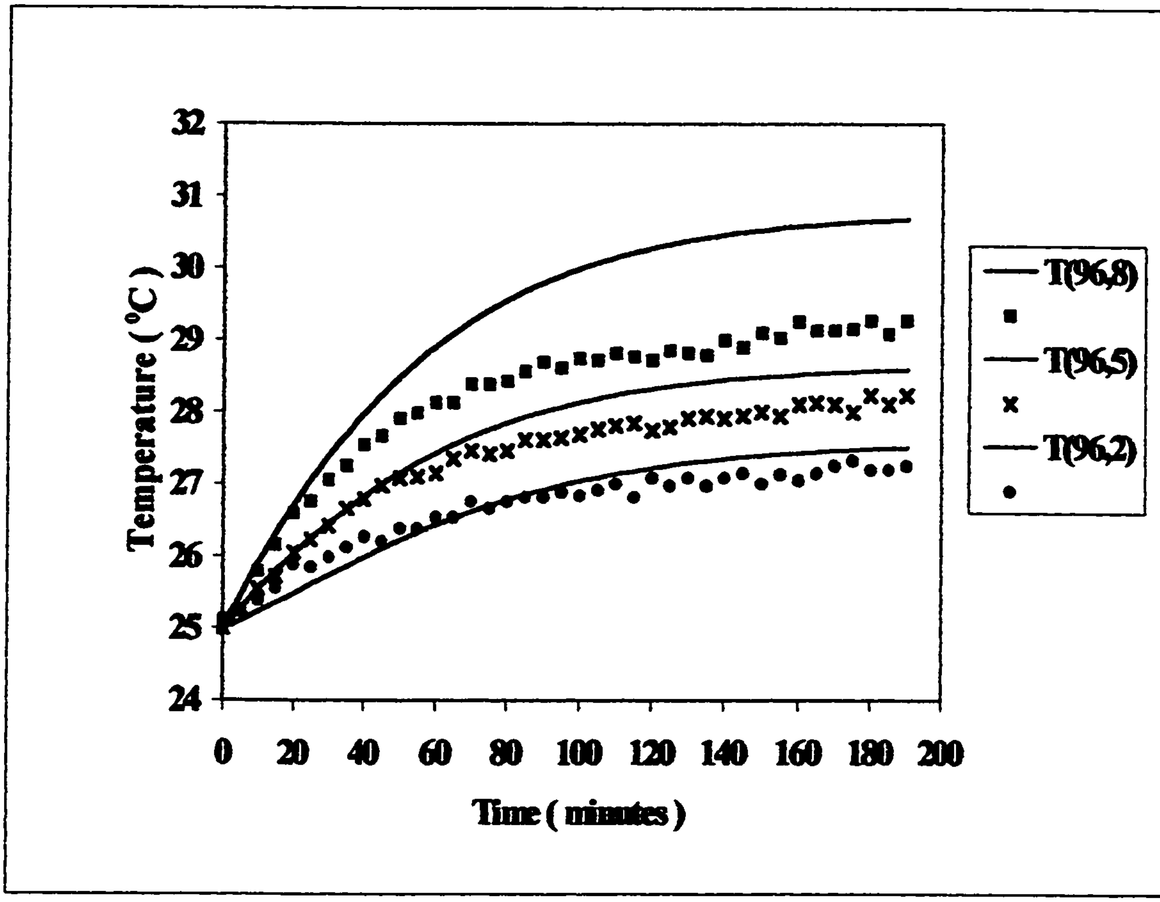


Figure 5.3: Measured and Predicted Radial Temperature Trend for Large Sphere, d_p =5.25 cm, Run # 2 at x = 96 cm, Re = 1268.1, Q_w = 243.4 W/m^2.

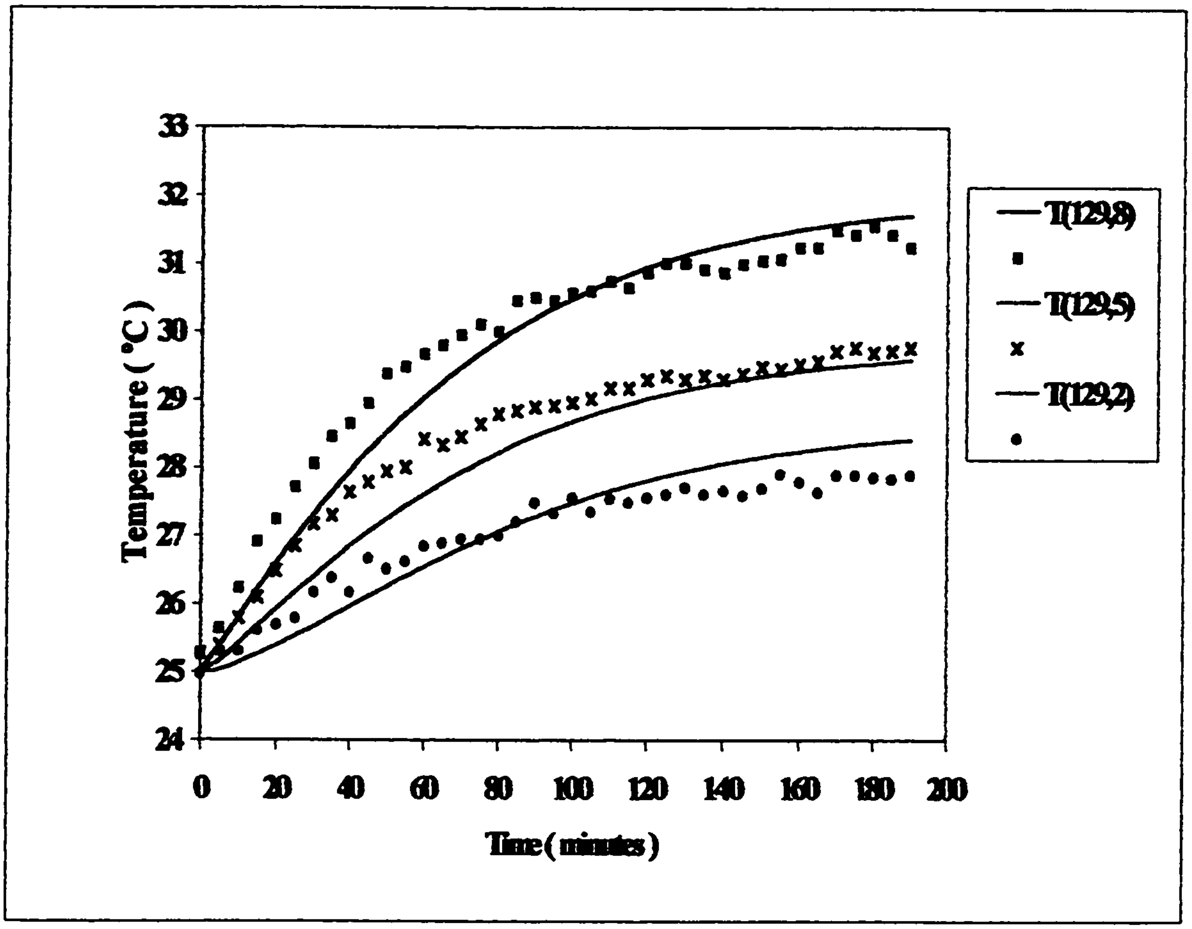


Figure 5.4: Measured and Predicted Radial Temperature Trend for Large Sphere, d_p =5.25 cm, Run # 2 at x = 129 cm, Re = 1268.1, Q_w = 243.4 W/m^2.

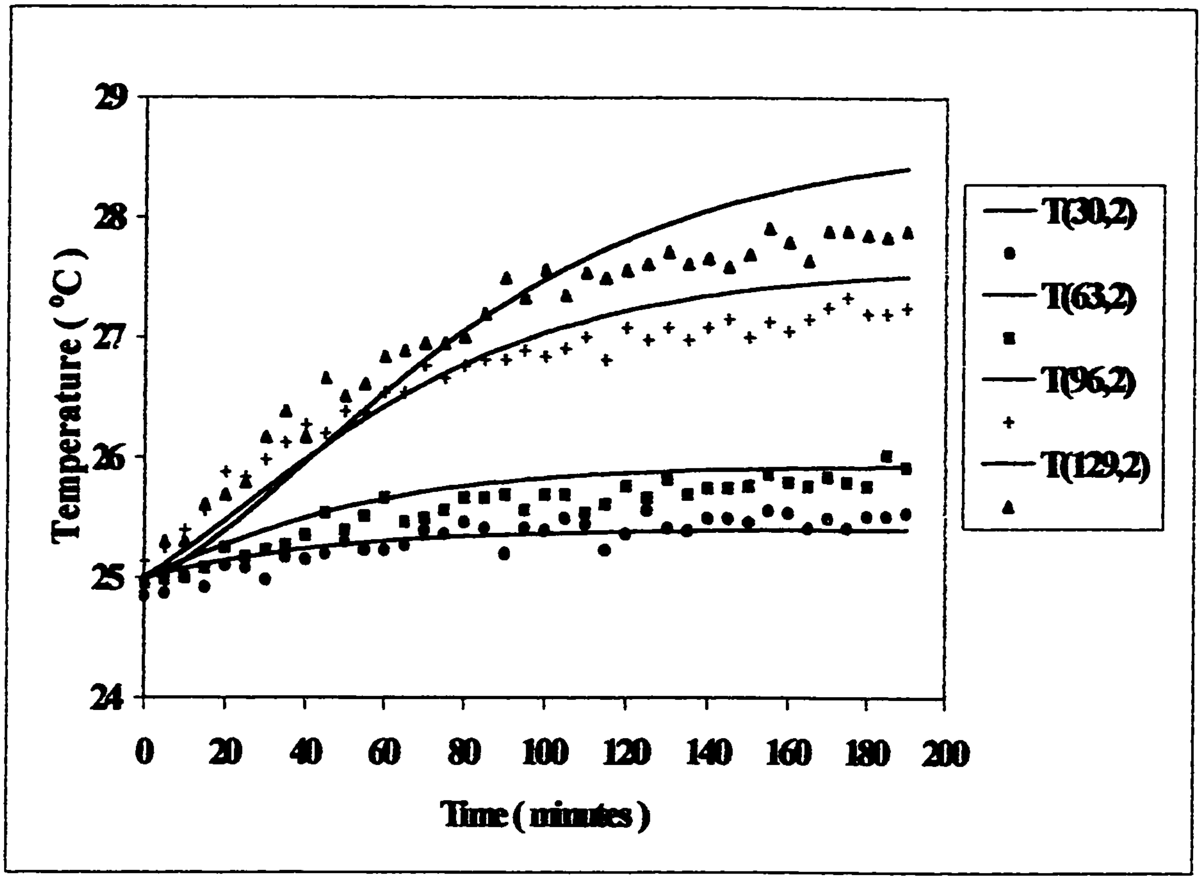


Figure 5.5: Measured and Predicted Axial Temperature Trend For Large Sphere, d_p = 5.25 cm, Run # 2 at y = 2 cm, Re = 1268.1, Q_w = 243.4 W/m^2.

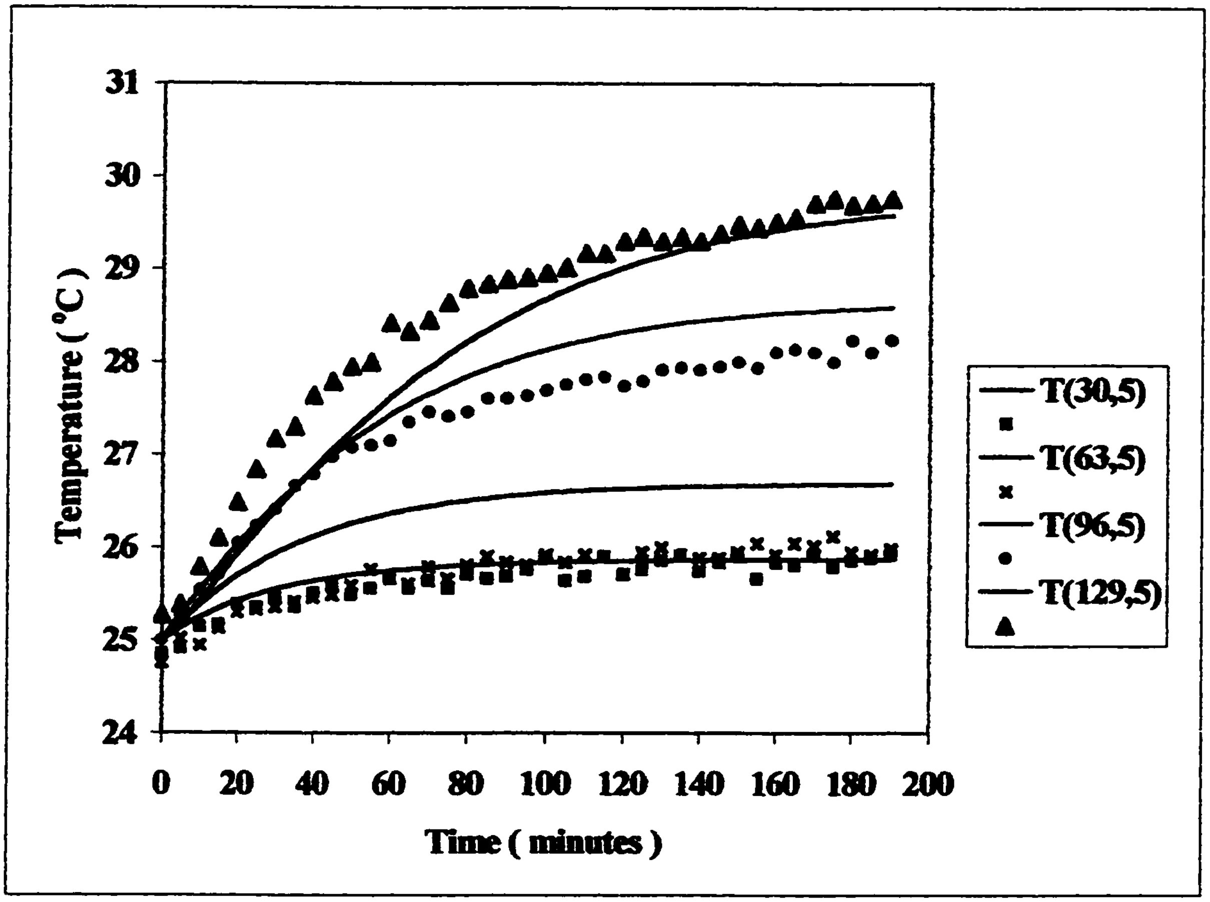


Figure 5.6: Measured and Predicted Axial Temperature Trend For Large Sphere, d_p = 5.25 cm, Run # 2 at y = 5 cm, Re = 1268.1 Q_w = 243.4 W/m^2.

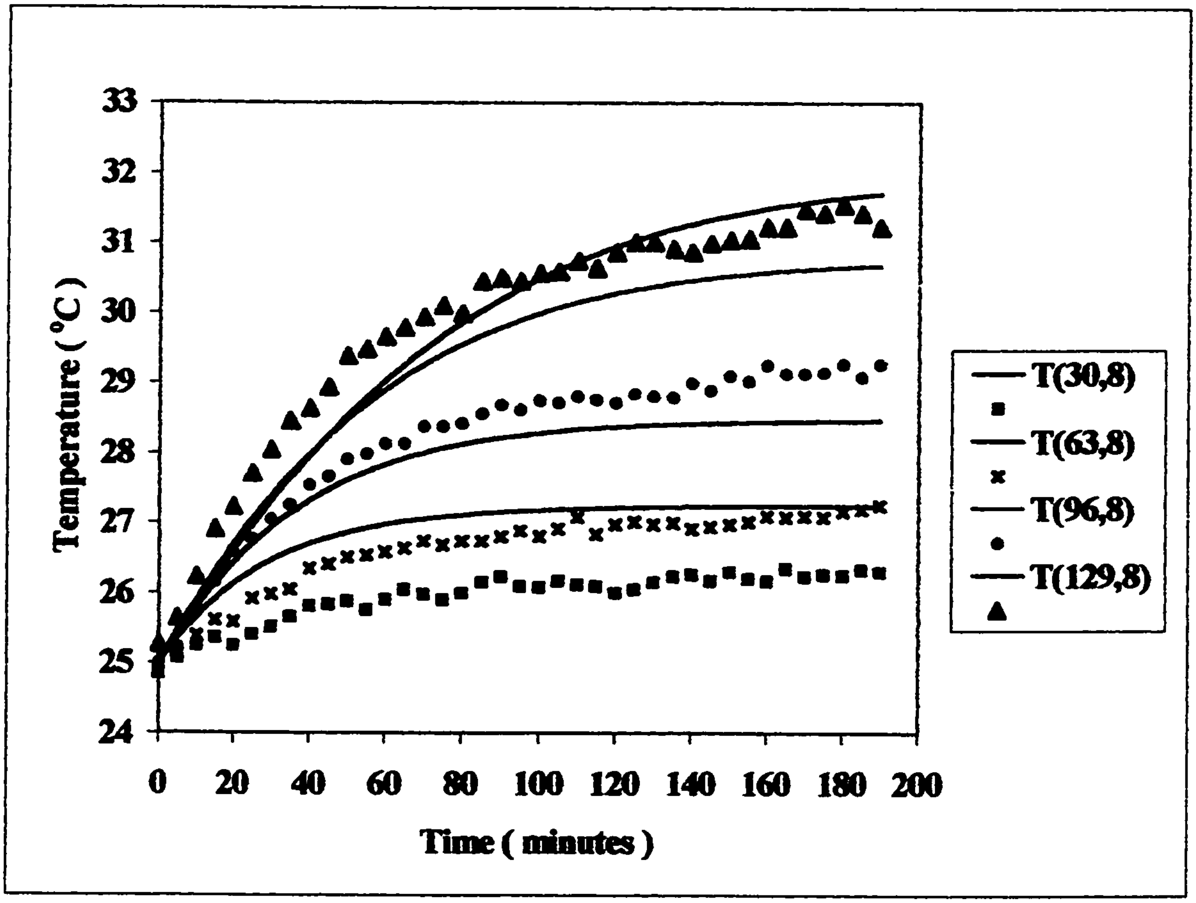


Figure 5.7: Measured and Predicted Axial Temperature Trend For Large Sphere, d_p = 5.25 cm, Run # 2 at y = 8 cm, Re = 1268.1, Q_w = 243.4 W/m^2.

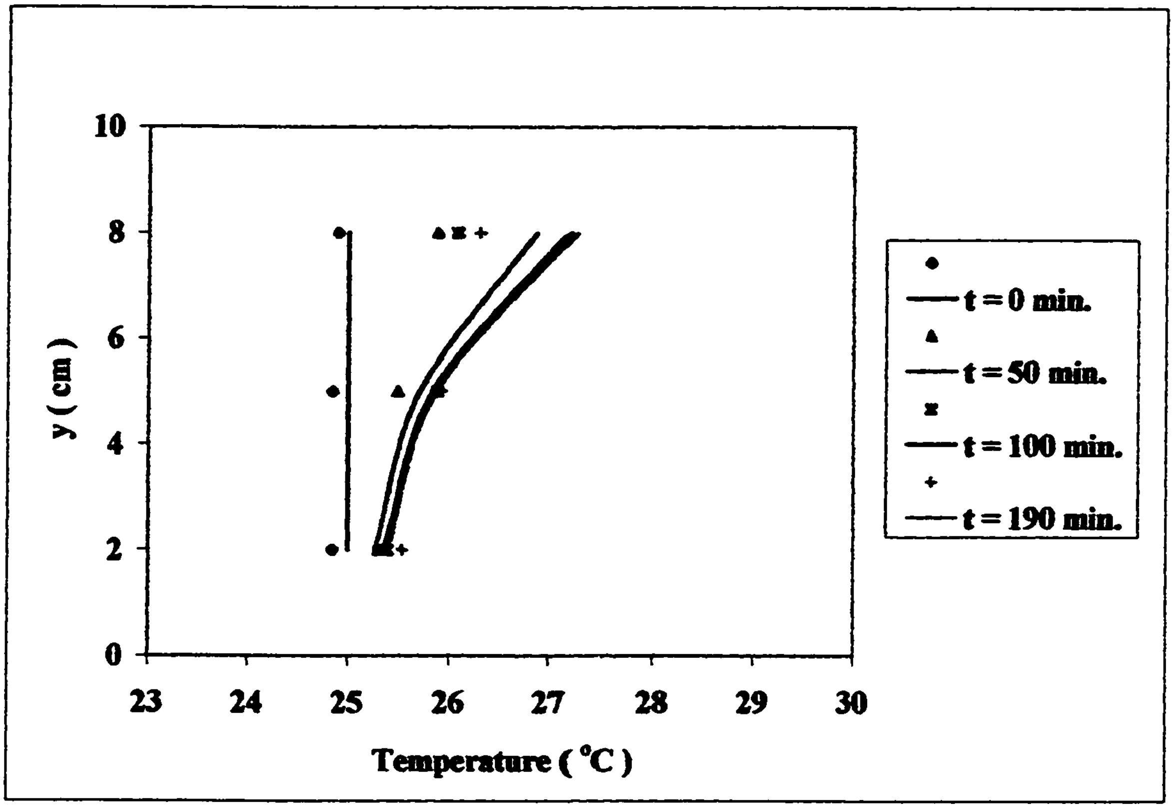


Figure 5.8: Measured and Predicted Radial Temperature Trend For Large Sphere, $d_p = 5.25$ cm, Run # 2 at x = 30 cm, Re = 1268.1, Q_w = 243.4 W/m^2.

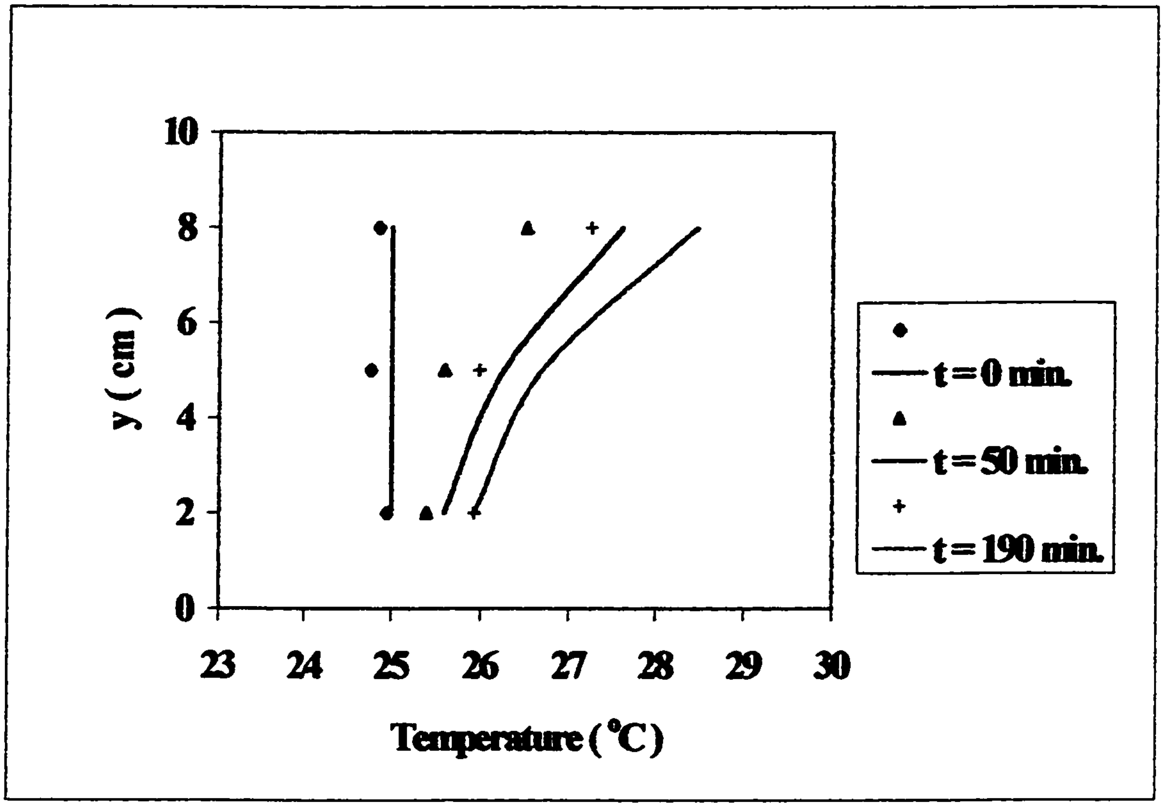


Figure 5.9: Measured and Predicted Radial Temperature Trend For Large Sphere, d_p = 5.25 cm, Run # 2 at x= 63 cm, Re = 1268.1, Q_w = 243.4 W/m^2.

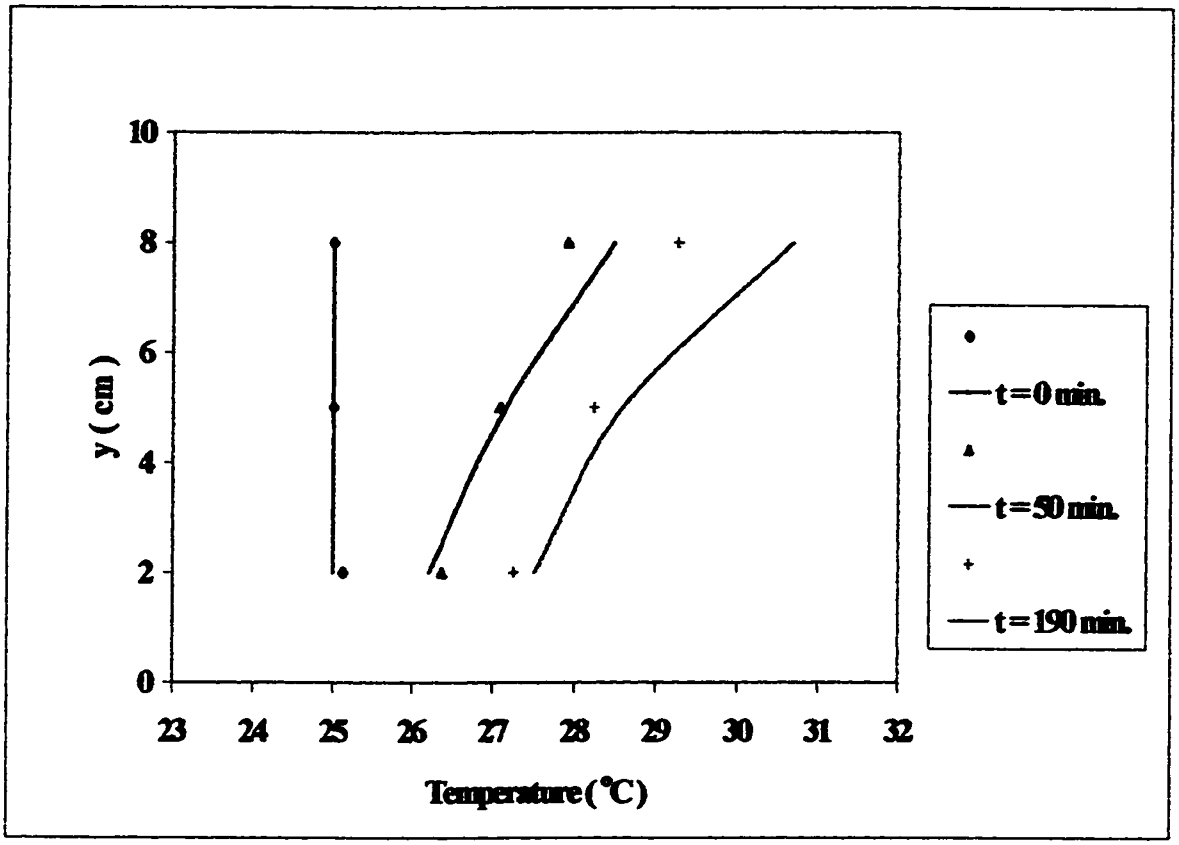


Figure 5.10: Measured and Predicted Radial Temperature Trend For Large Sphere, d_p = 5.25 cm, Run # 2 at x= 96 cm, Re = 1268.1, Q_w = 243.4 W/m^2.

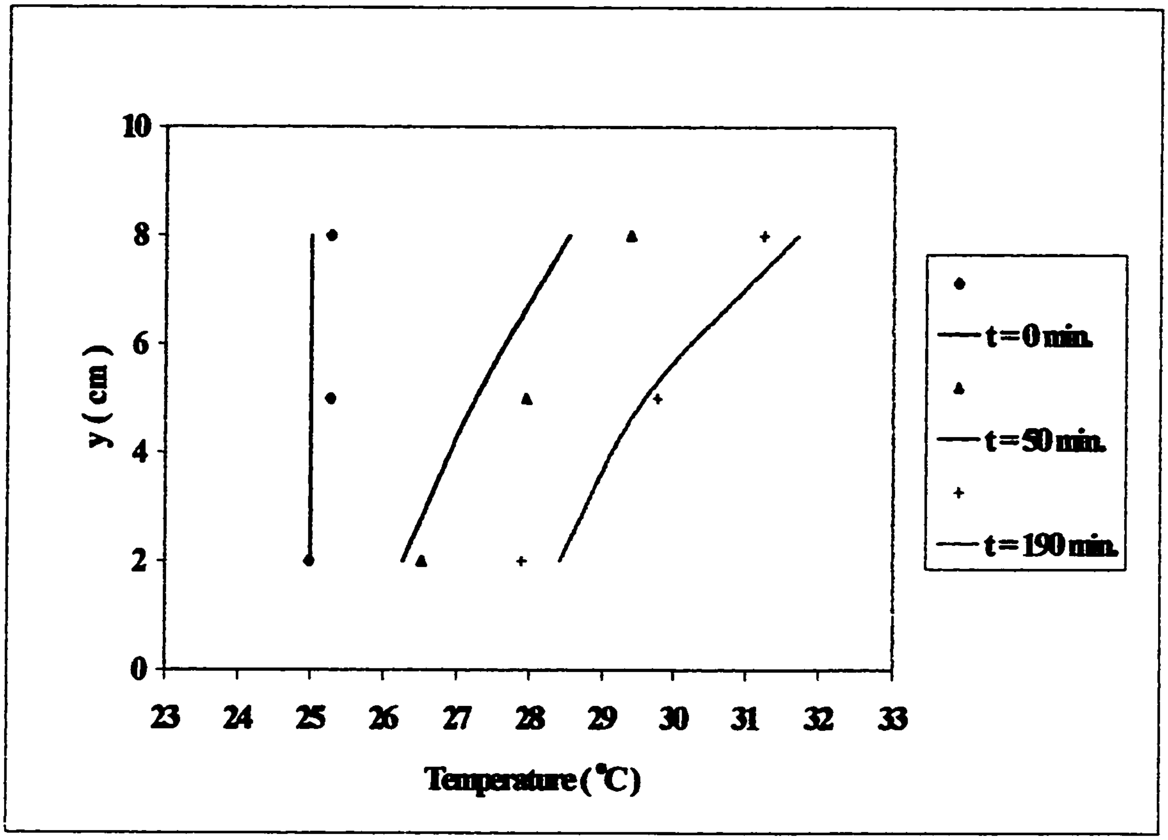


Figure 5.11: Measured and Predicted Radial Temperature Trend For Large Sphere, d_p = 5.25 cm, Run # 2 at x= 129 cm, Re = 1268.1, Q_w = 243.4 W/m^2.

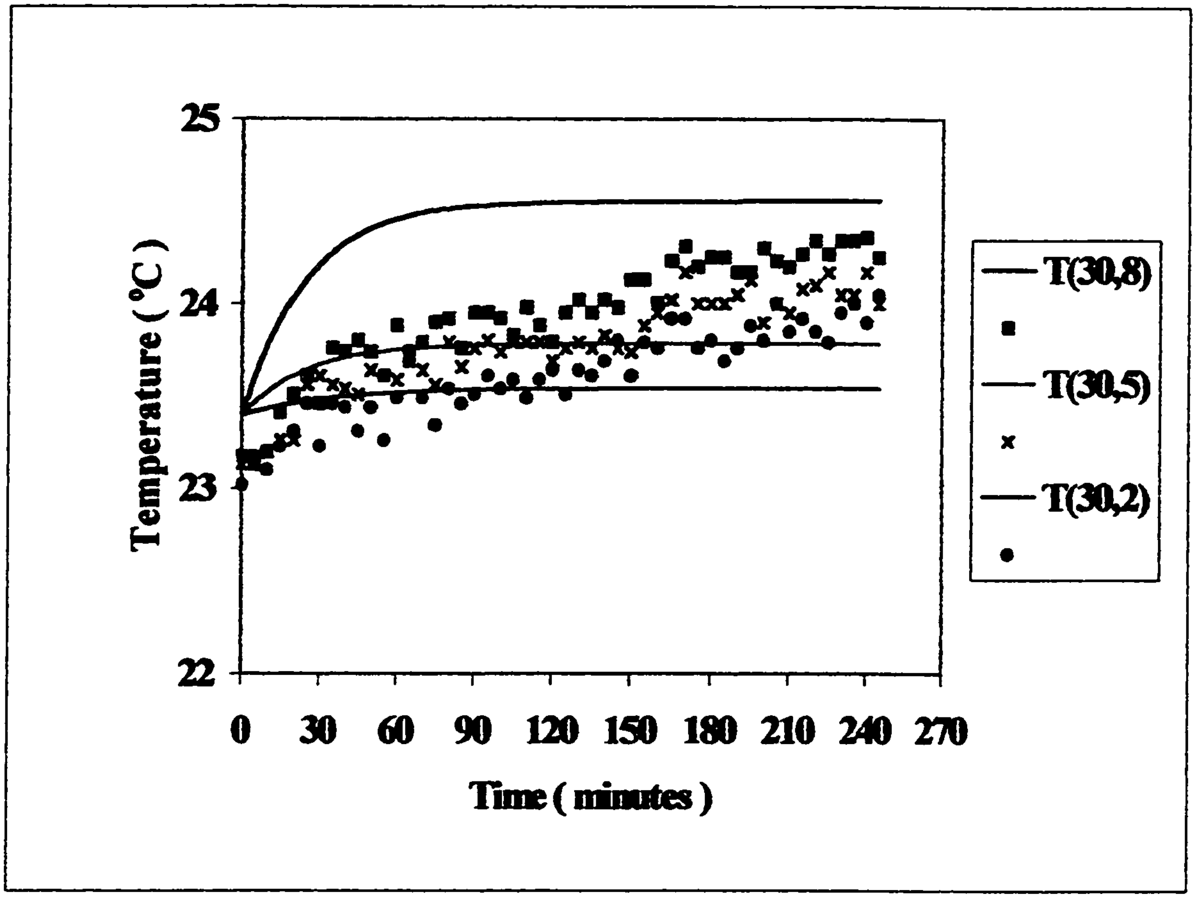


Figure 5.12: Measured and Predicted Radial Temperature Trend For Medium Sphere, d_p = 3.87 cm, Run # 7 at x = 30 cm, Re = 672.6, Q_w = 79.4 W/m^2.

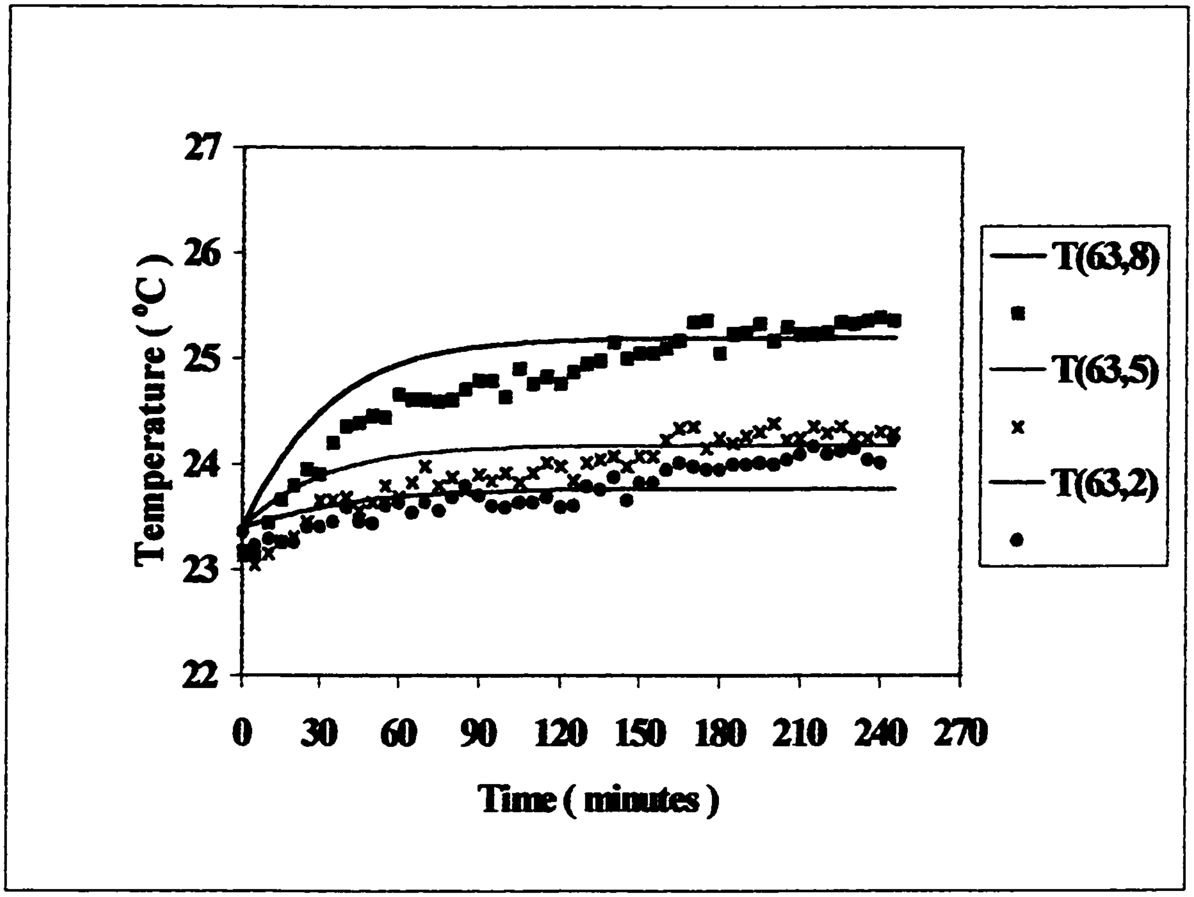


Figure 5.13: Measured and Predicted Radial Temperature Trend For Medium Sphere, d_p = 3.87 cm, Run # 7 at x = 63 cm, Re = 672.6, Q_w = 79.4 W/m^2.

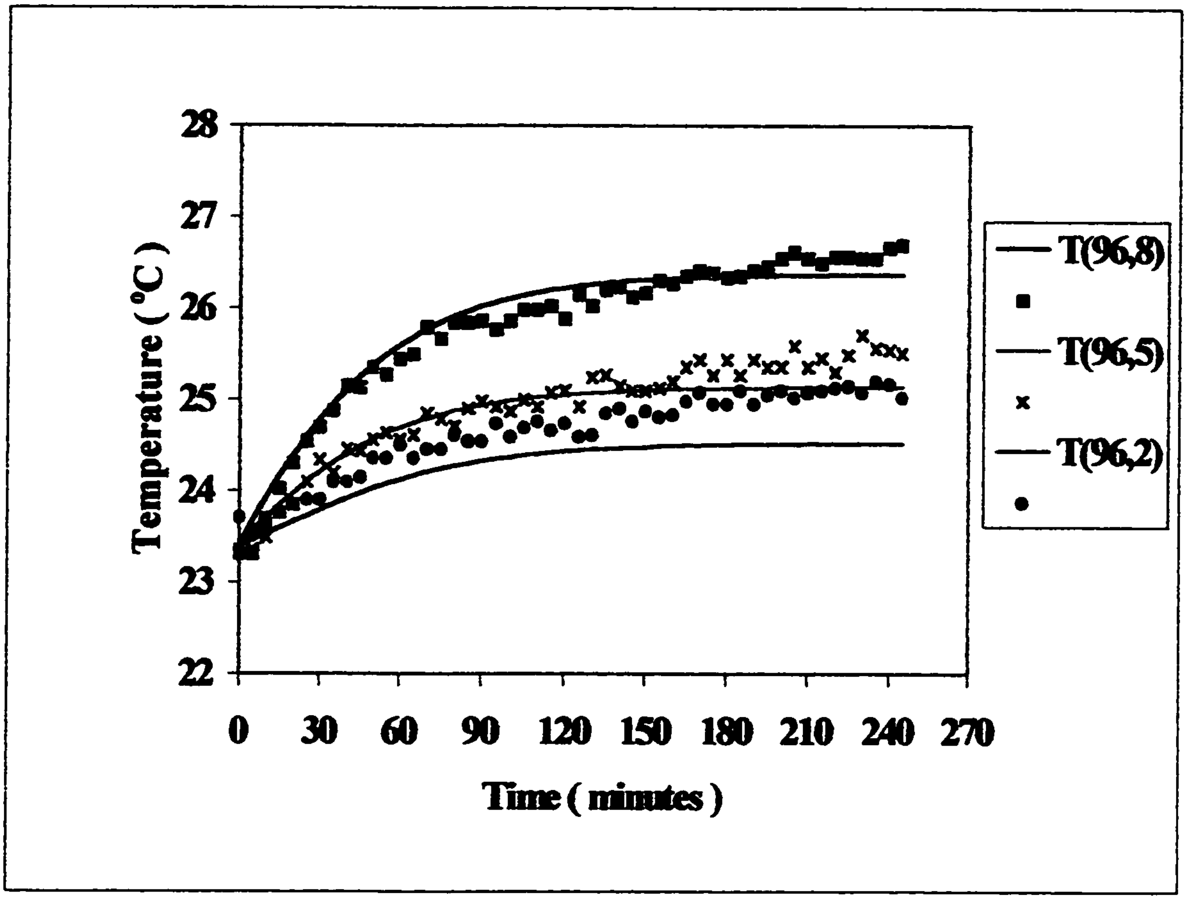


Figure 5.14: Measure and Predicted Radial Temperature Trend For Medium Sphere, d_p = 3.87 cm, Run # 7 at x = 96 cm, Re = 672.6, Q_w = 79.4 W/m^2.

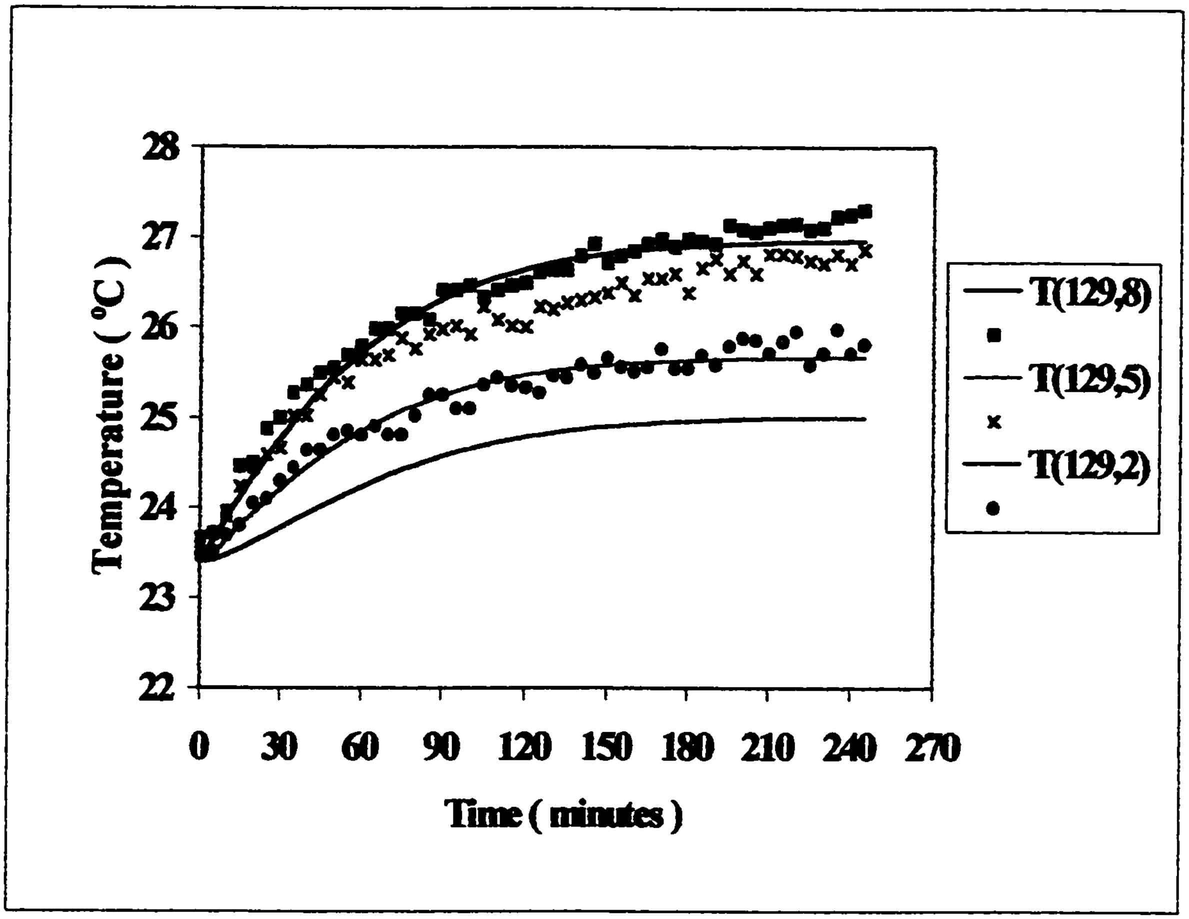


Figure 5.15: Measured and Predicted Radial Temperature Trend For Medium Sphere, d_p = 3.87 cm, Run # 7 at x = 129 cm, Re = 672.6, Q_w = 79.4 W/m^2.

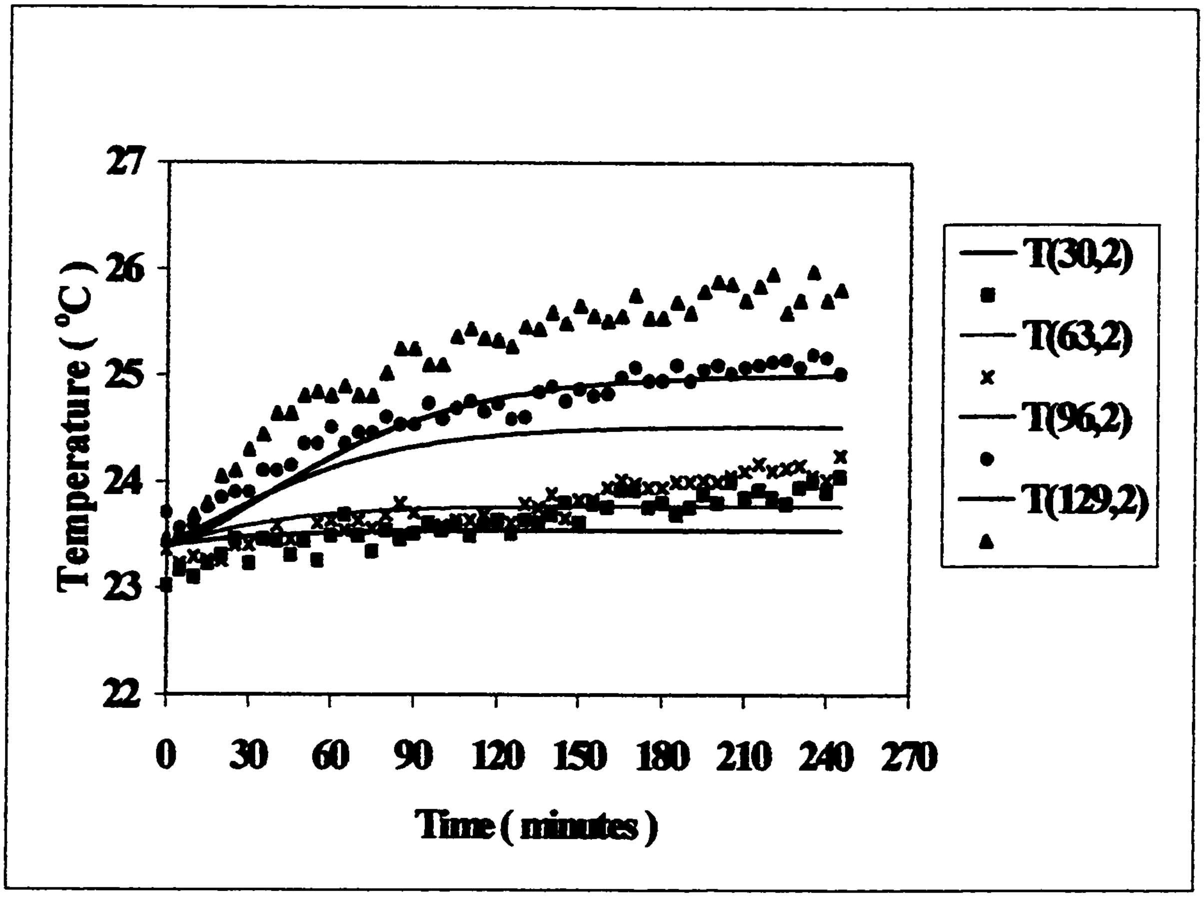


Figure 5.16: Measured and Predicted Axial Temperature Trend For Medium Sphere, d_p = 3.78 cm. Run # 7 at y = 2 cm, Re = 672.6, Q_w = 79.4 W/m^2.

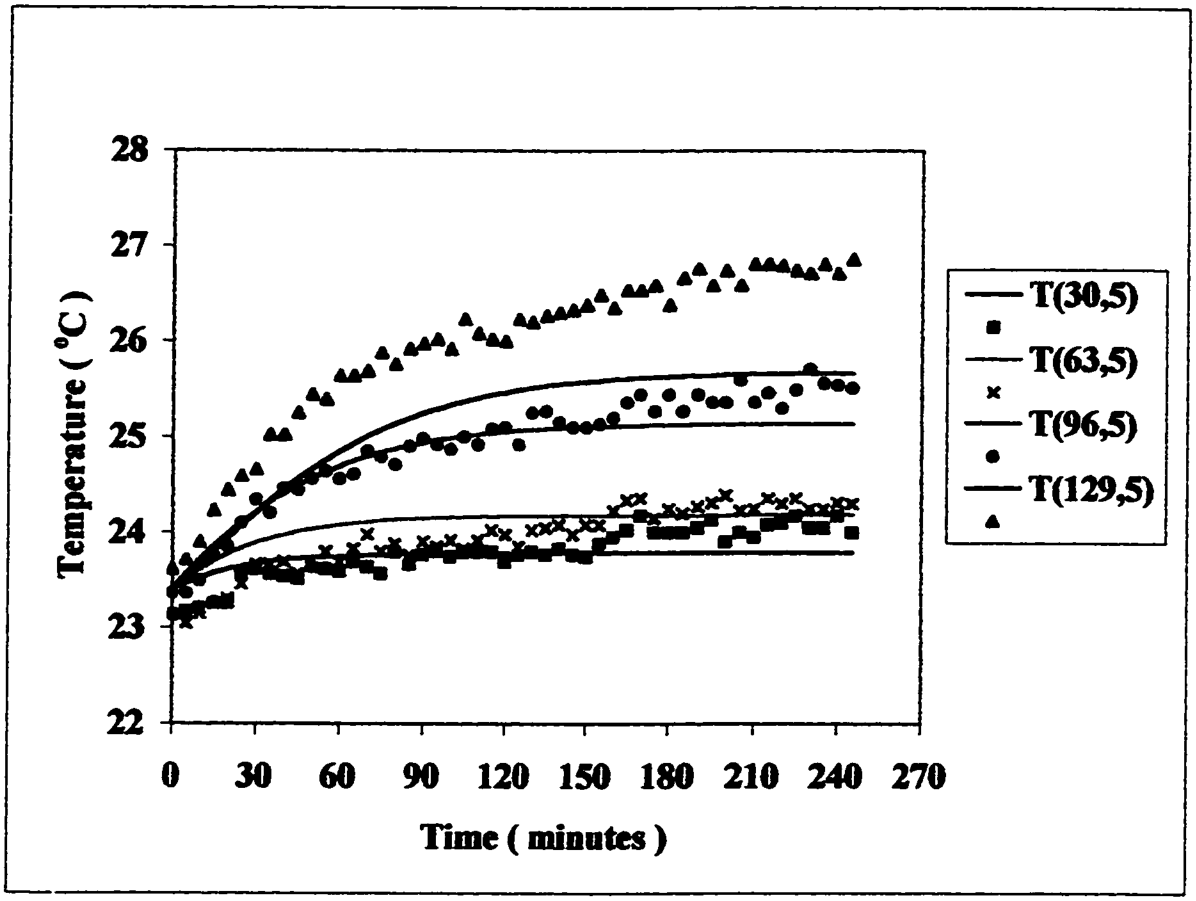


Figure 5.17: Measured and Predicted Axial Temperature Trend For Medium Sphere, d_p = 3.78 cm. Run # 7 at y = 5 cm, Re = 672.6, Q_w = 79.4 W/m^2.

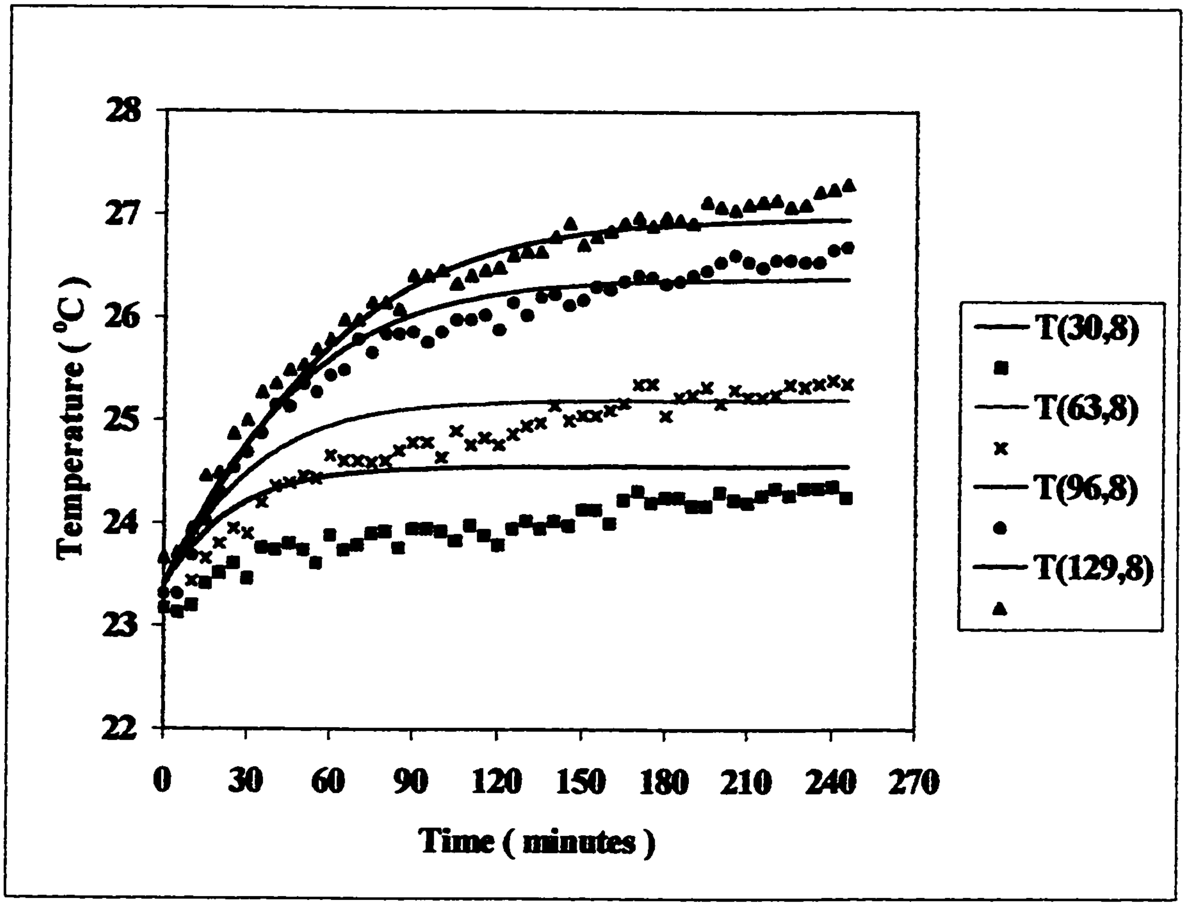


Figure 5.18: Measured and Predicted Axial Temperature Trend For Medium Sphere, d_p = 3.78 cm. Run # 7 at y = 8 cm, Re = 672.6, Q_w = 79.4 W/m^2.

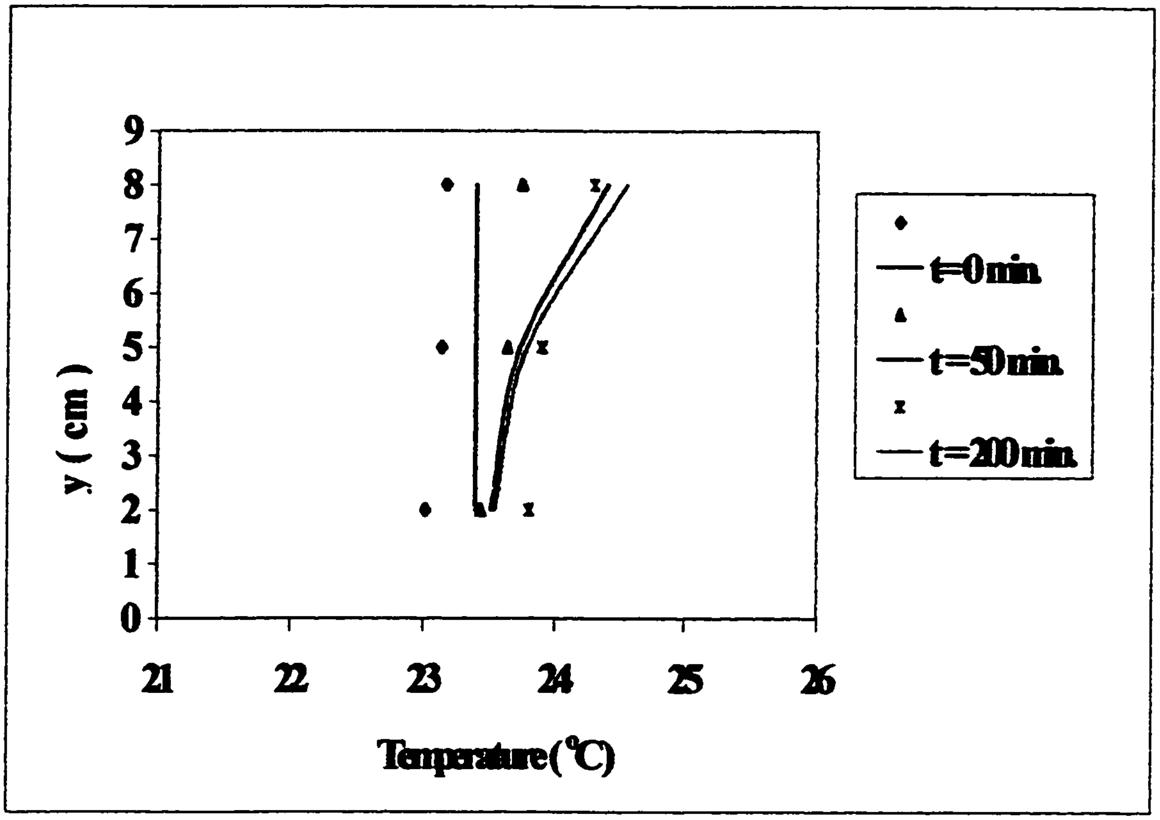


Figure 5.19: Measured and Predicted Radial Temperature Trend For Medium Sphere, d_p = 3.87 cm, Run # 7 at x= 30 cm, Re = 672.6, Q_w = 79.4 W/m^2.

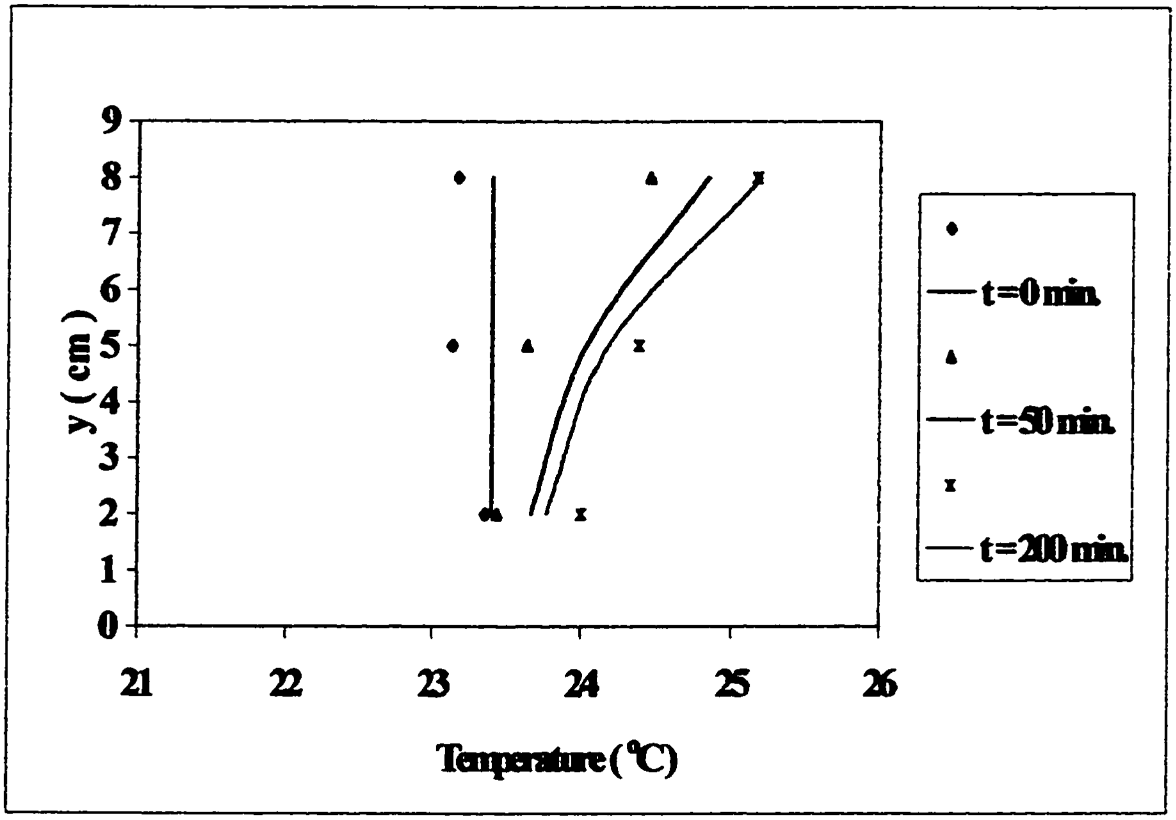


Figure 5.20: Measured and Predicted Radial Temperature Trend For Medium Sphere, d_p = 3.87 cm, Run # 7 at x = 63 cm, Re = 672.6, Q_w = 79.4 W/m^2.

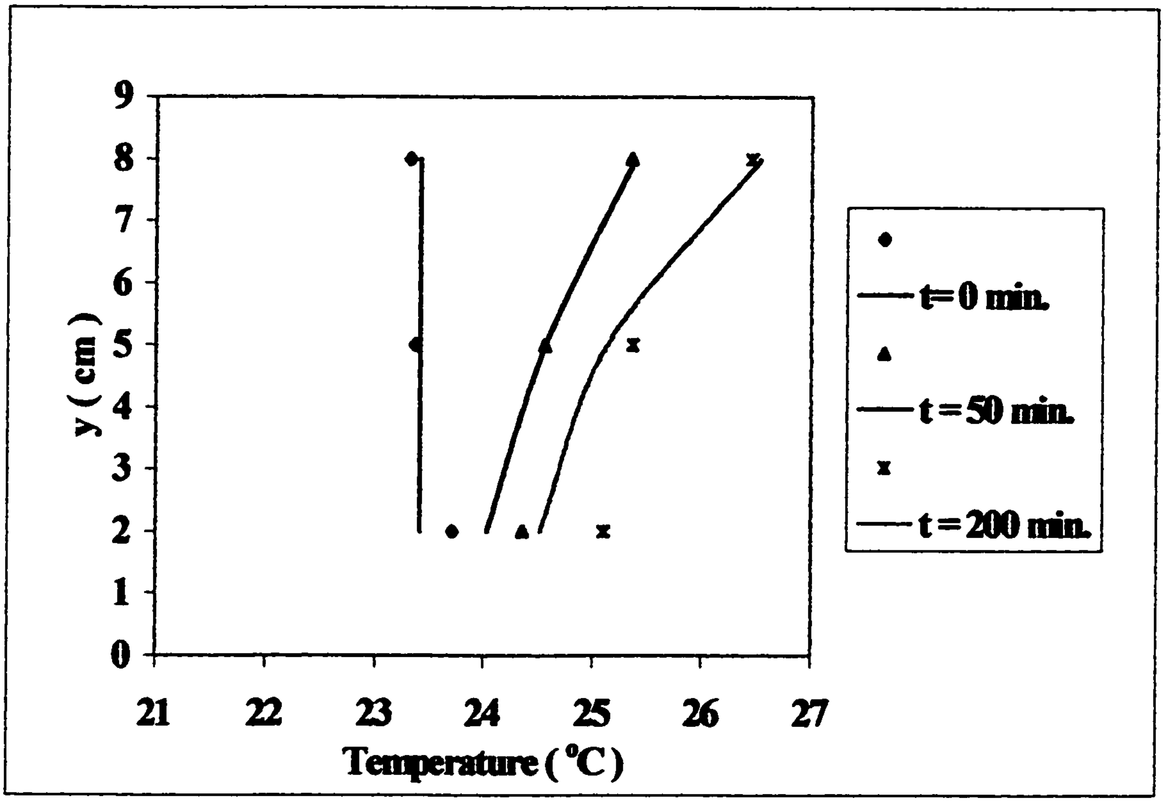


Figure 5.21: Measured and Predicted Radial Temperature Trend For Medium Sphere, d_p = 3.87 cm, Run # 7 at x= 96 cm, Re = 672.6, Q_w = 79.4 W/m^2.

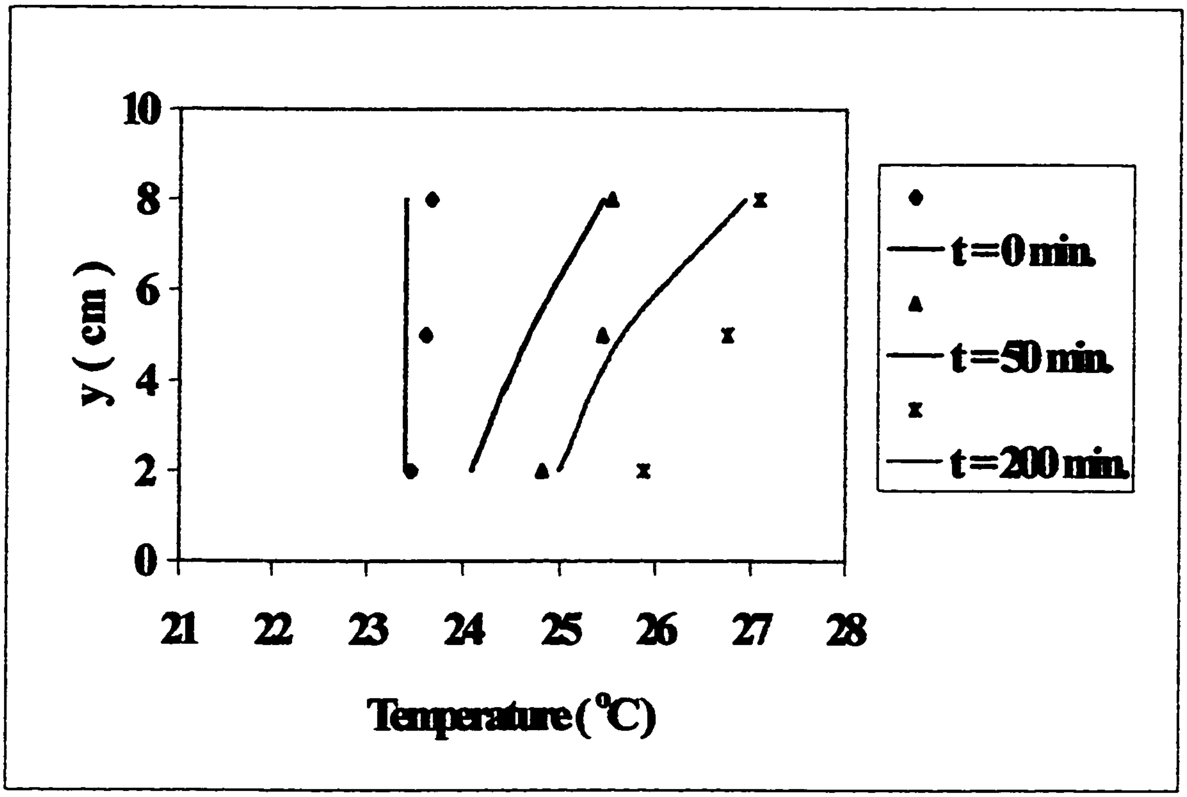


Figure 5.22: Measured and Predicted Radial Temperature Trend For Medium Sphere, d_p = 3.87 cm, Run # 7 at x= 129 cm, Re = 672.6, Q_w = 79.4 W/m^2.

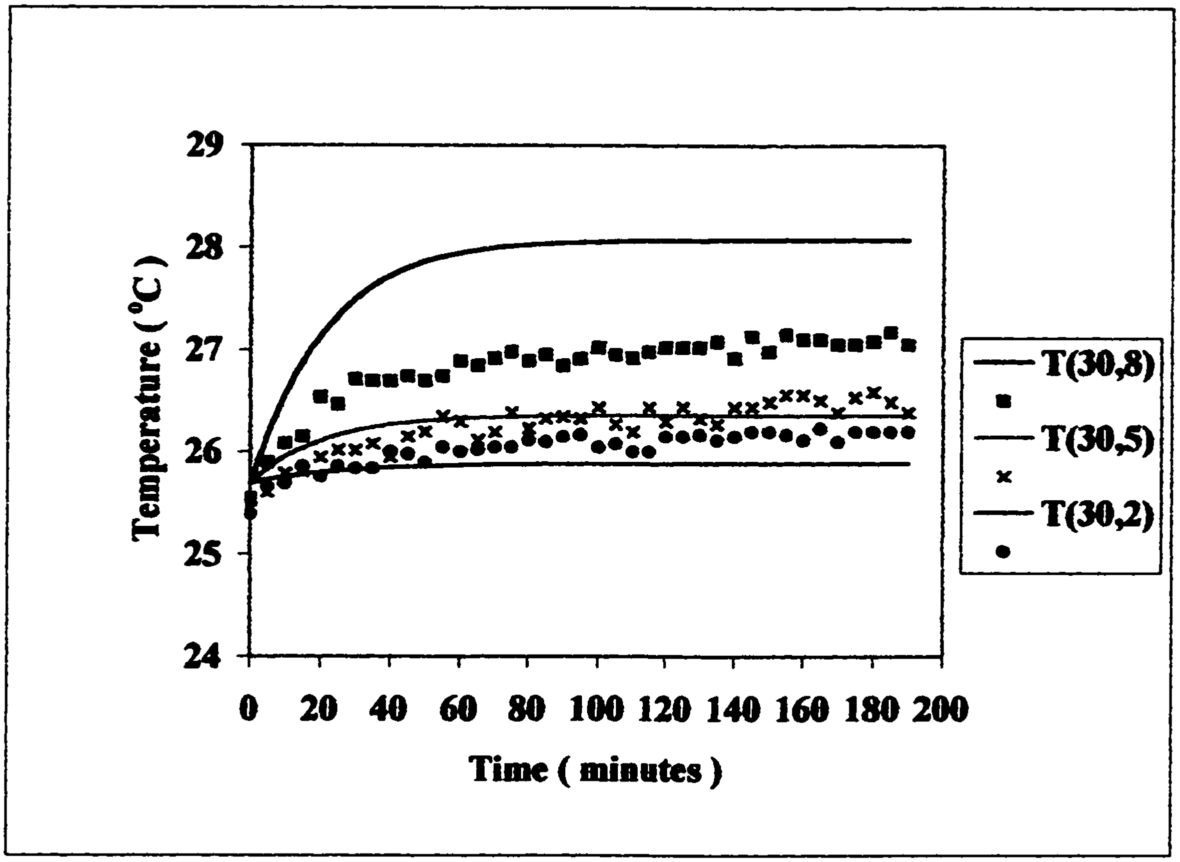


Figure 5.23: Measured and Predicted Radial Temperature Trend For Small Sphere, d_p = 2.9 cm, Run # 2 at x= 30 cm, Re = 756, Q_w = 243.4 W/m^2.

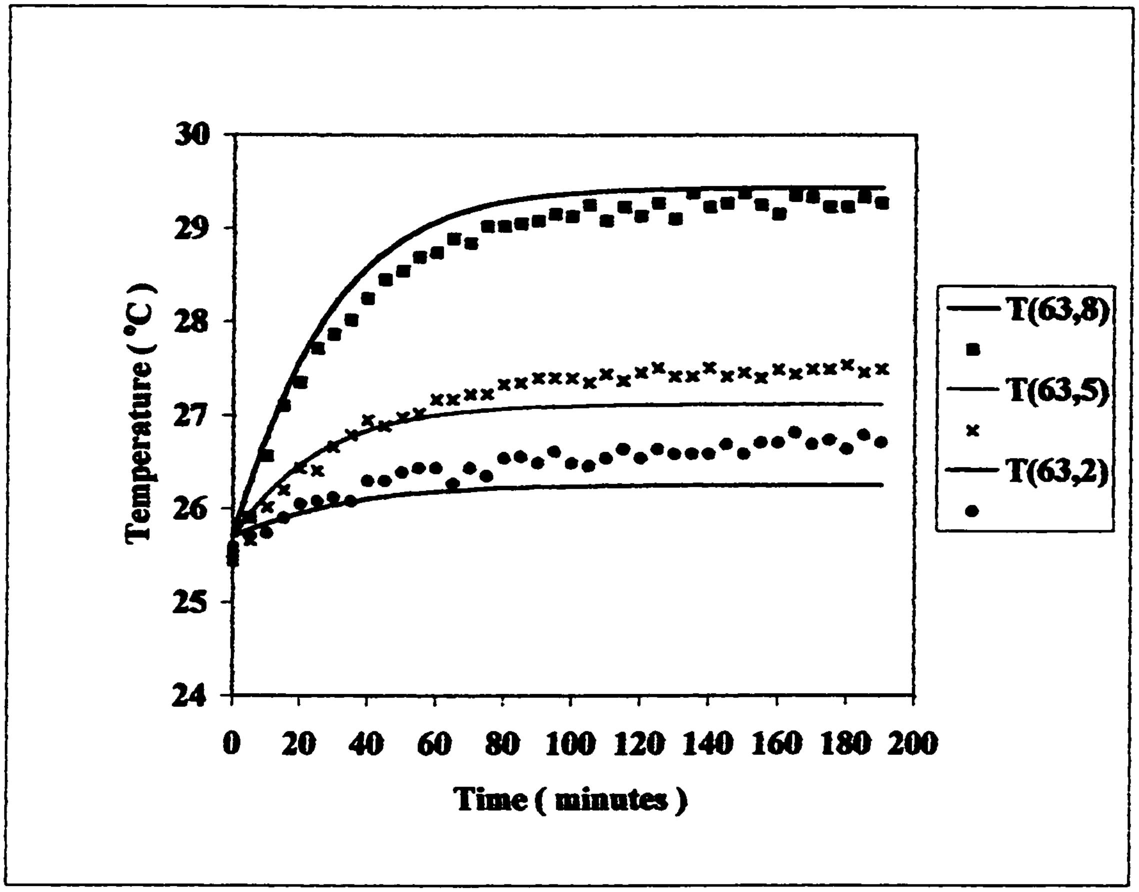


Figure 5.24: Measured and Predicted Radial Temperature Trend For Small Sphere, d_p = 2.9 cm. Run # 2 at x= 63 cm, Re = 756, Q_w = 243.4 W/m^2.

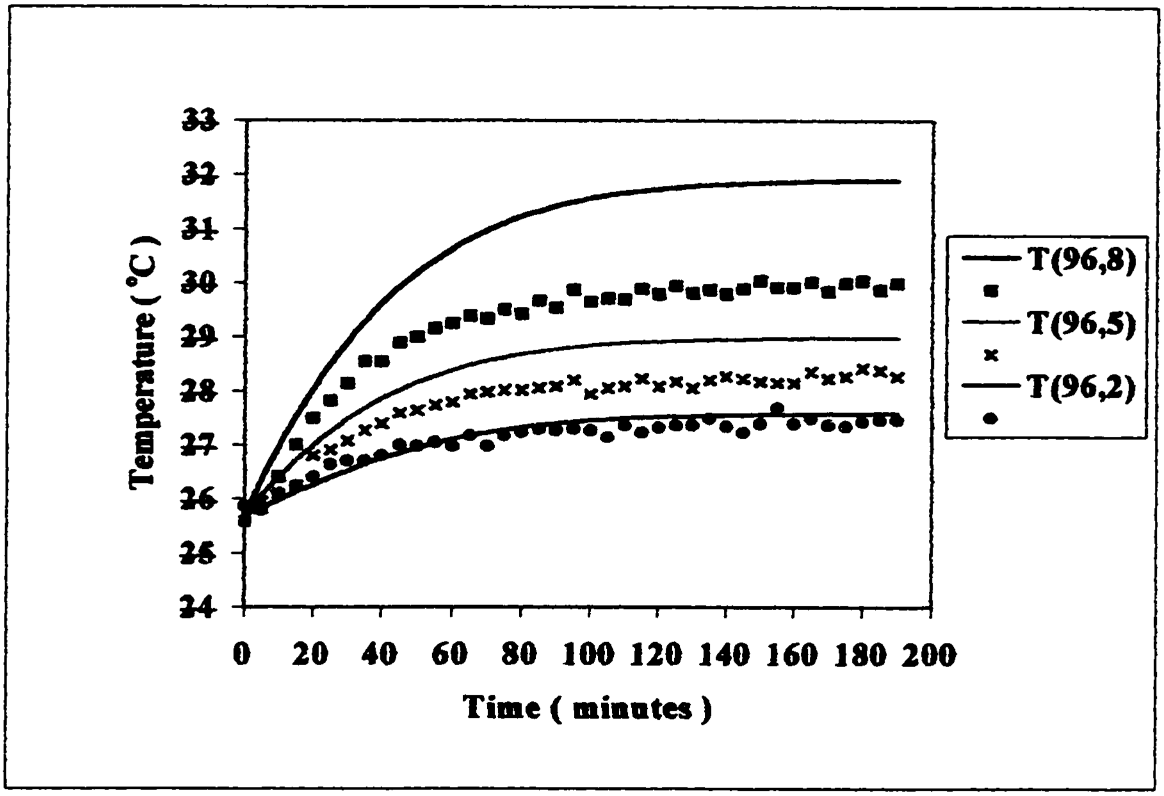


Figure 5.25: Measured and Predicted Radial Temperature Trend For Small Sphere, d_p = 2.9 cm, Run # 2 at x= 96 cm, Re = 756, Q_w = 243.4 W/m^2.

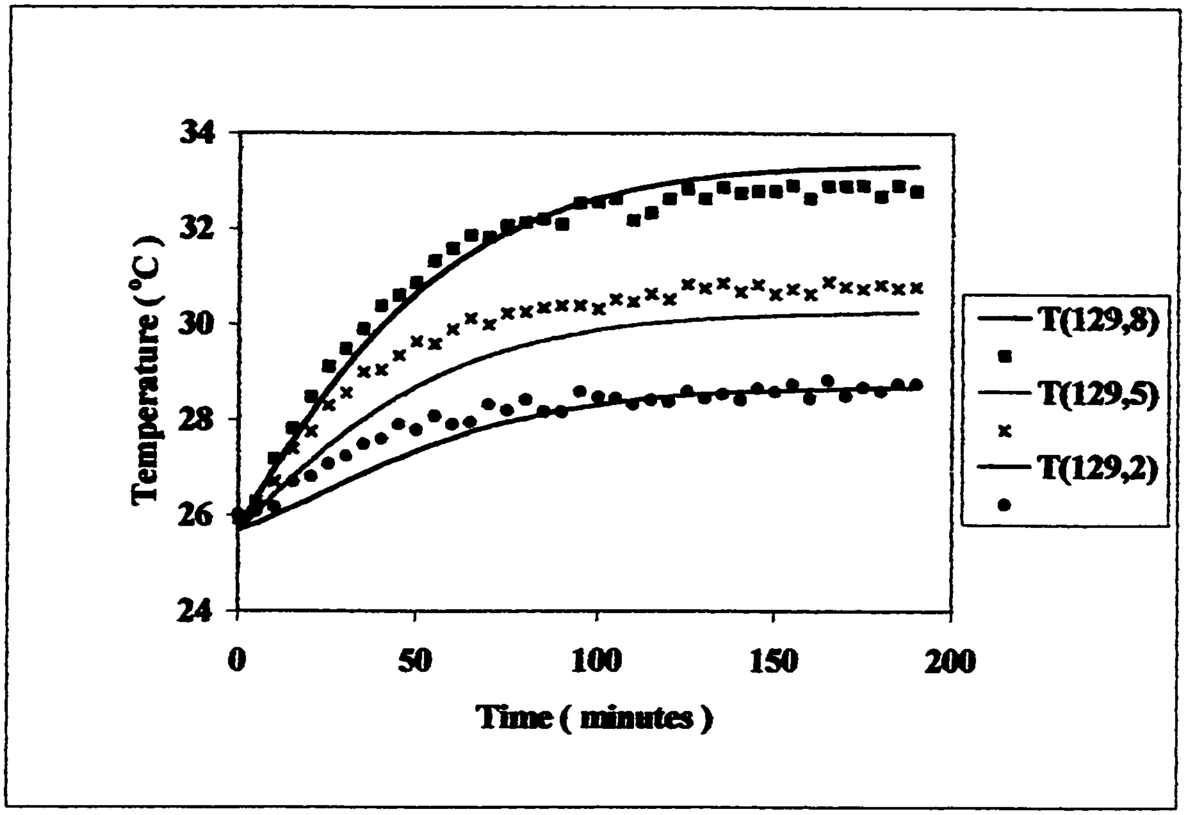


Figure 5.26: Measured and Predicted Radial Temperature Trend For Small Sphere, d_p = 2.9 cm, Run # 2 at x= 129 cm, Re = 756, Q_w = 243.4 W/m^2.

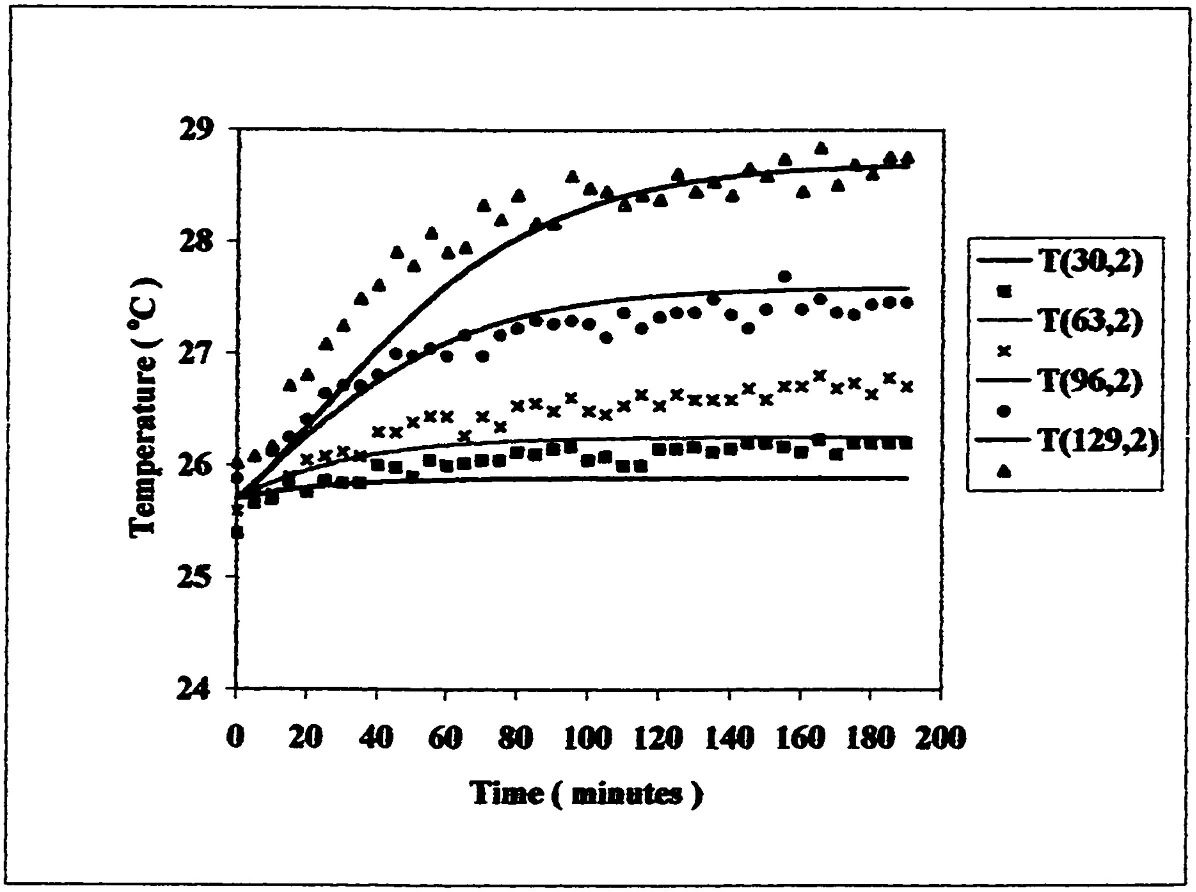


Figure 5.27: Measured and Predicted Axial Temperature Trend For Small Sphere, $d_p = 2.9$ cm, Run # 2 at $y = 2$ cm, Re = 756, $Q_w = 243.4\ W/m^2$.

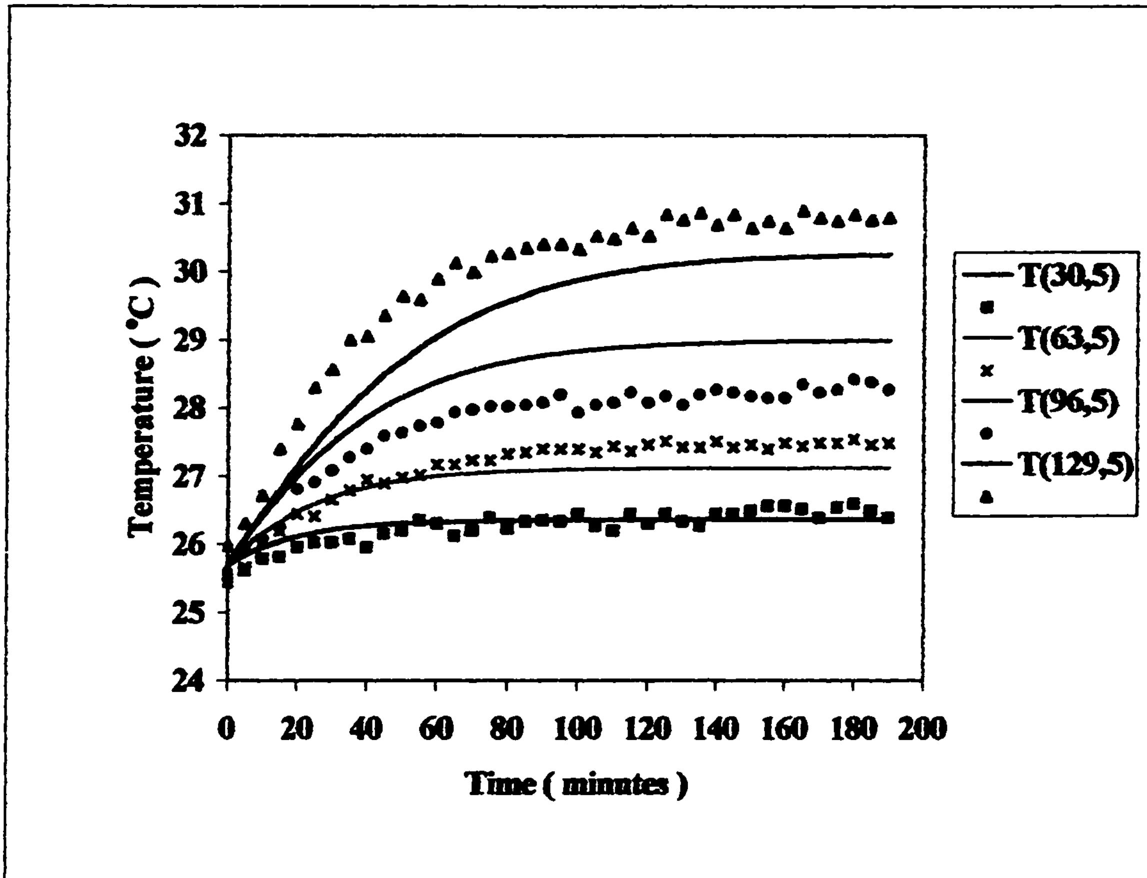


Figure 5.28: Measured and Predicted Axial Temperature Trend For Small Sphere, d_p = 2.9 cm, Run # 2 at y = 5 cm, Re = 756, Q_w = 243.4 W/m^2.

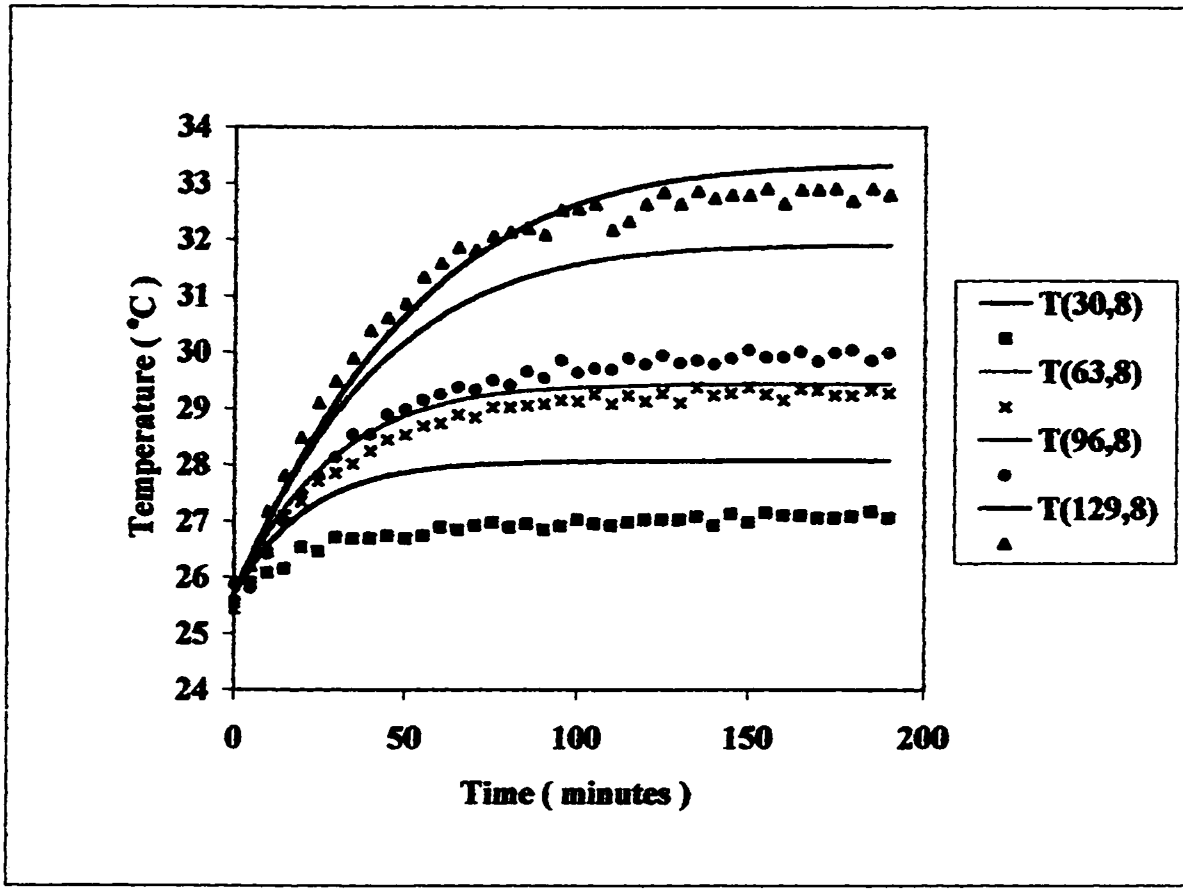


Figure 5.29: Measured and Predicted Axial Temperature Trend For Small Sphere, d_p = 2.9 cm, Run # 2 at y = 8 cm, Re = 756, Q_w = 243.4 W/m^2.

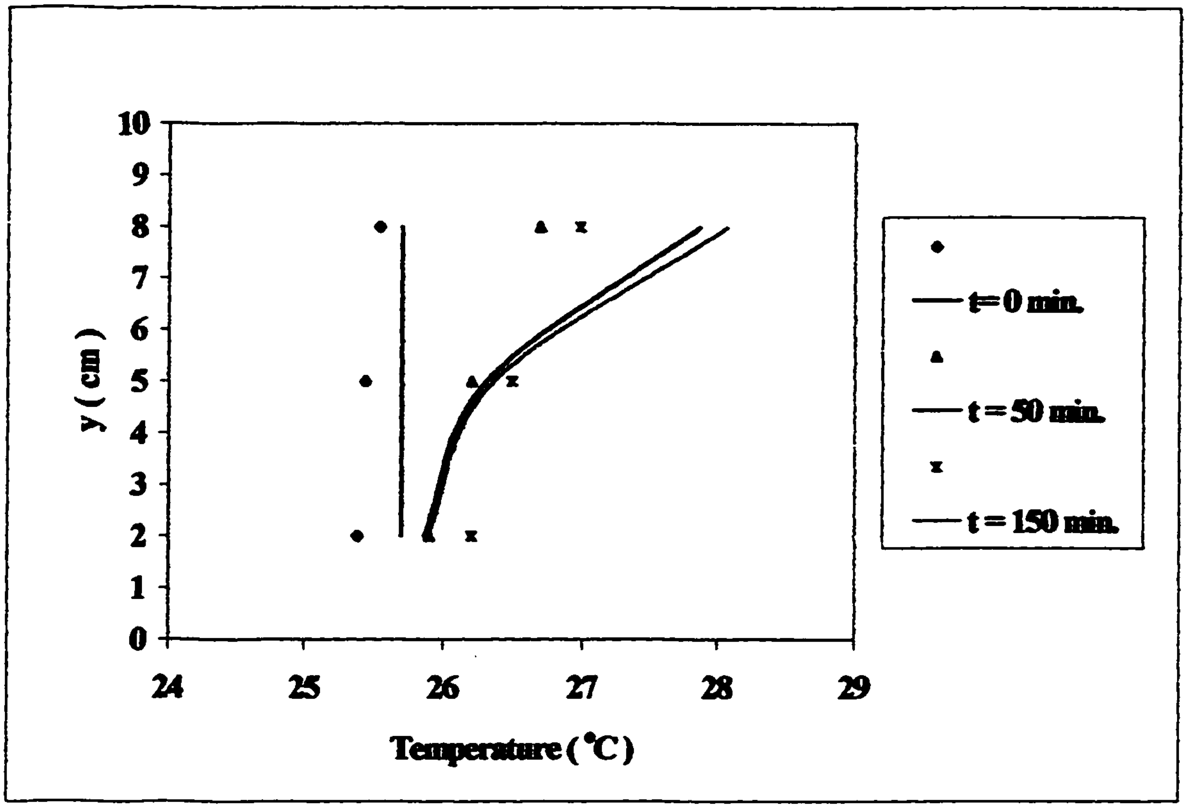


Figure 5.30: Measured and Predicted Radial Temperature Trend For Small Sphere, d_p = 2.9 cm, Run # 2 at x= 30 cm, Re = 756, Q_w = 243.4 W/m^2.

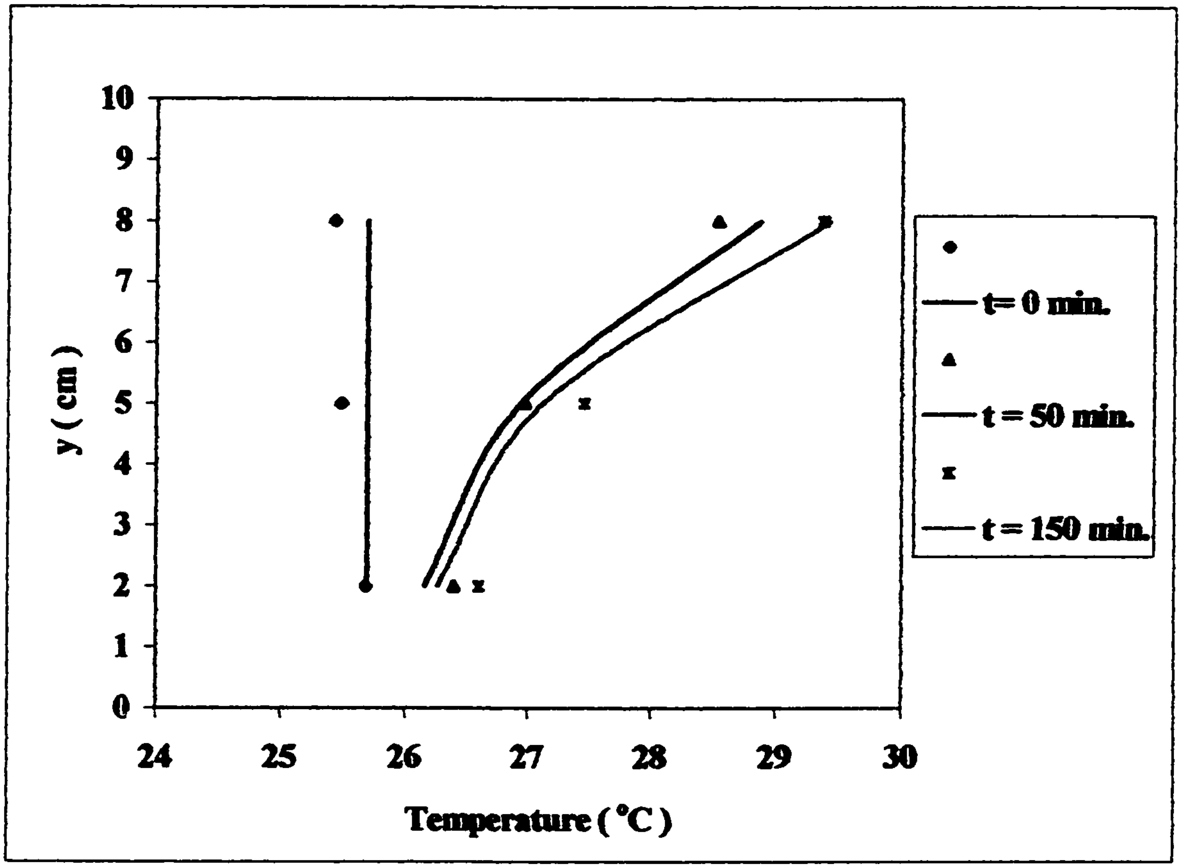


Figure 5.31: Measured and Predicted Radial Temperature Trend For Small Sphere, d_p = 2.9 cm, Run # 2 at x= 63 cm, Re = 756, Q_w = 243.4 W/m^2.

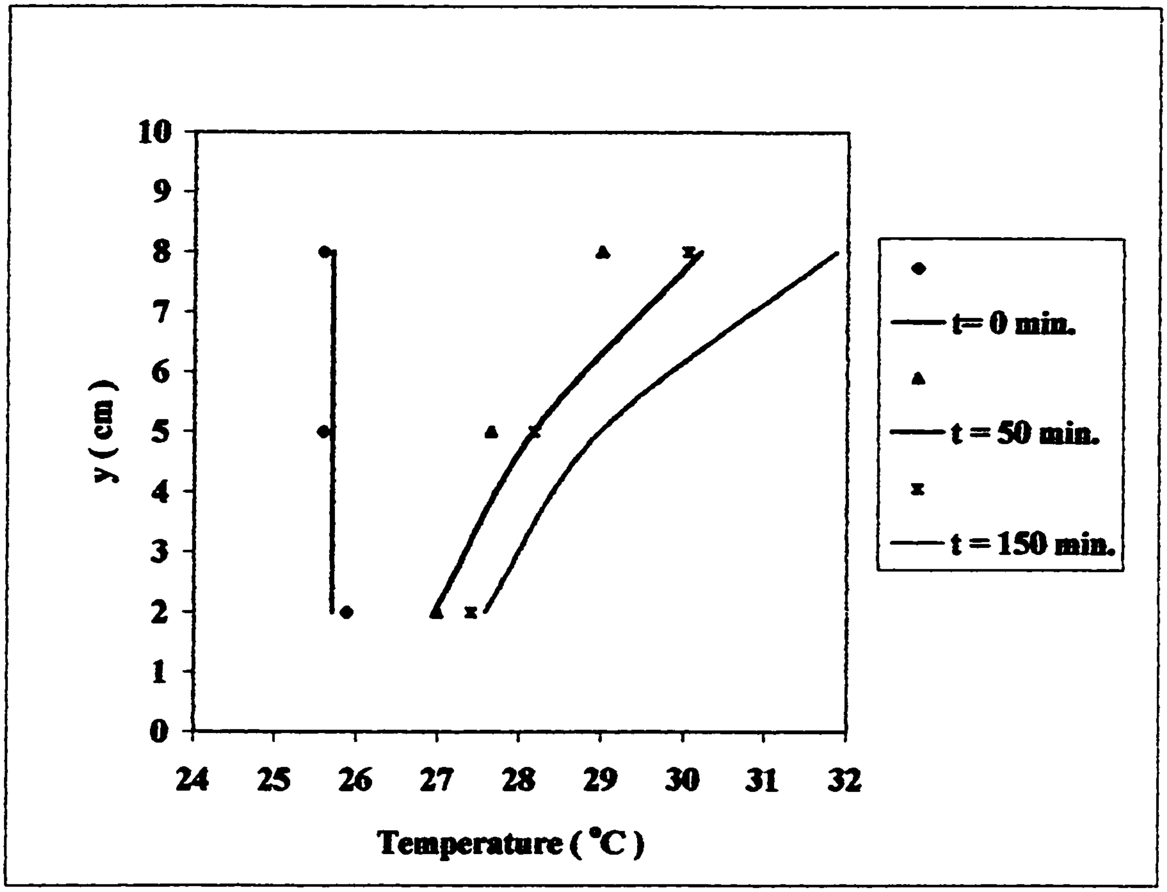


Figure 5.32: Measured and Predicted Radial Temperature Trend For Small Sphere, d_p = 2.9 cm, Run # 2 at x= 96 cm, Re = 756, Q_w = 243.4 W/m^2.

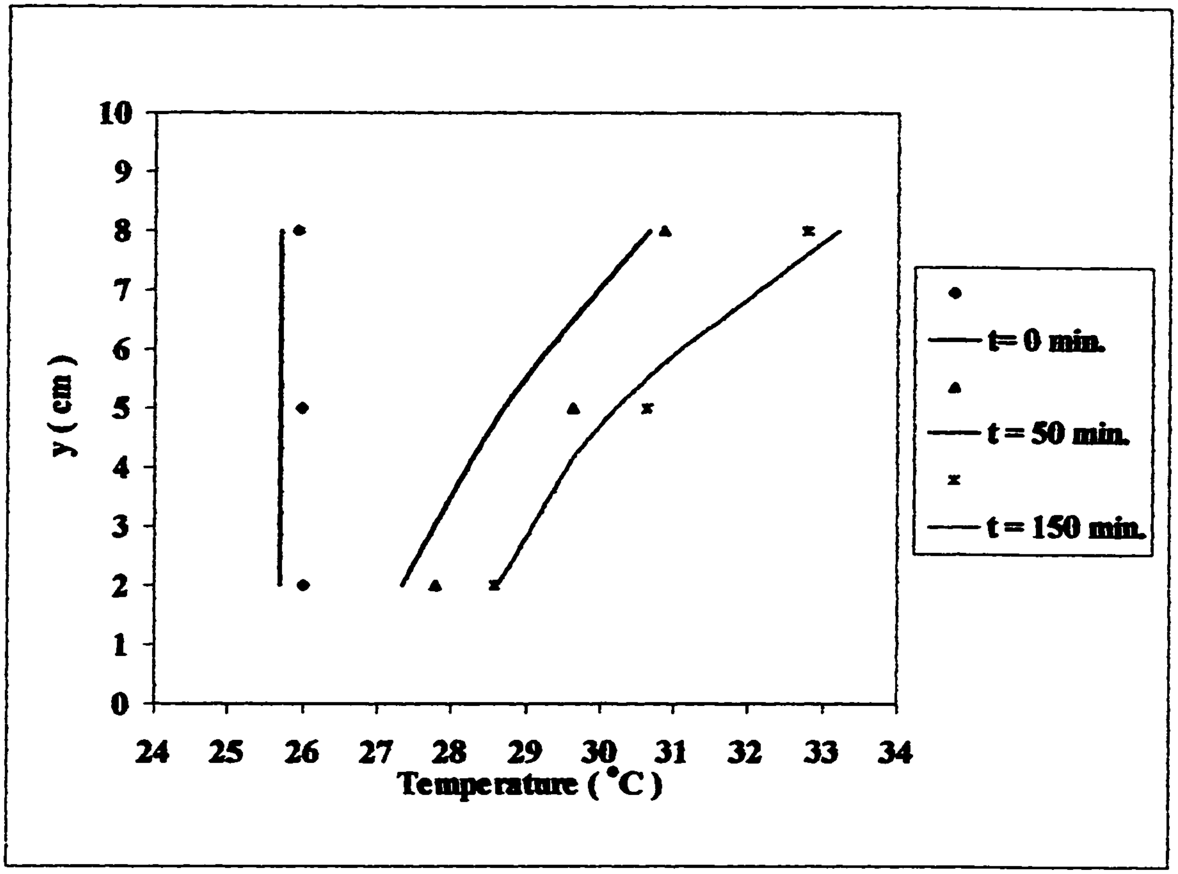


Figure 5.33: Measured and Predicted Radial Temperature Trend For Small Sphere, d_p = 2.9 cm, Run # 2 at x= 129 cm, Re = 756, Q_w = 243.4 W/m^2.

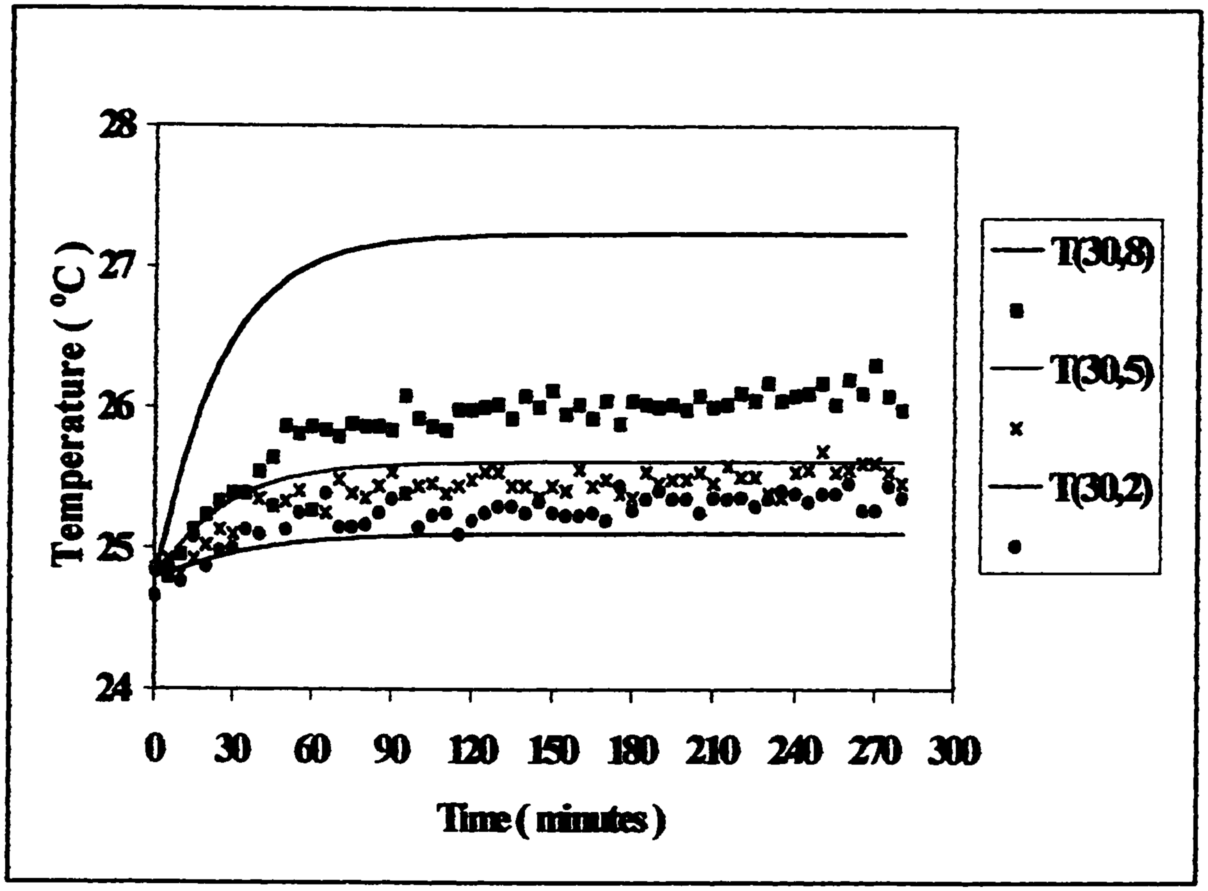


Figure 5.34: Measured and Predicted Radial Temperature Trend For Large Rashig Ring, $d_p = 3.87$ cm. Run # 7 at x = 30 cm. Re = 672.6; $Q_w = 179.2$ W/m^2.

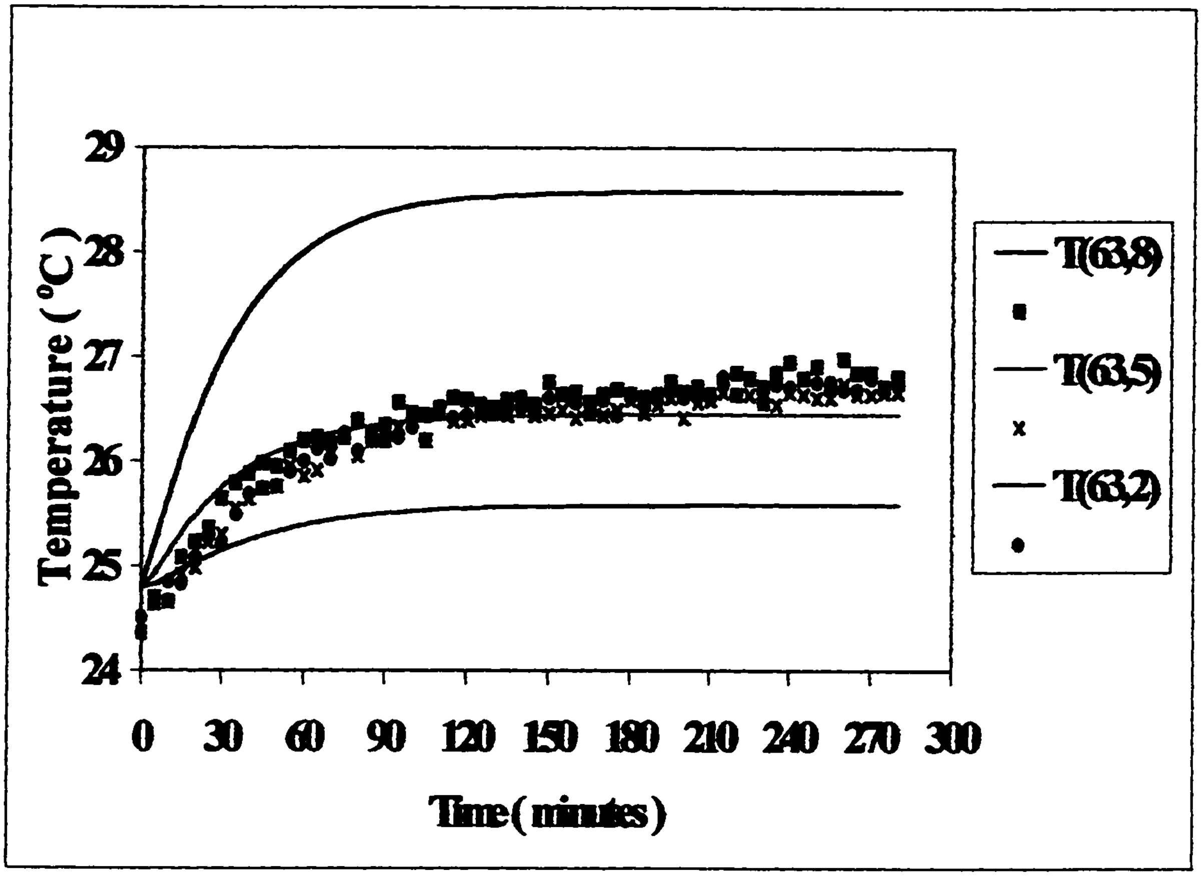


Figure 5.35: Measured and Predicted Radial Temperature Trend For Large Rashig Ring, $d_p = 3.87$ cm. Run # 7 at x = 63 cm. Re = 672.6; $Q_w = 179.2$ W/m^2.

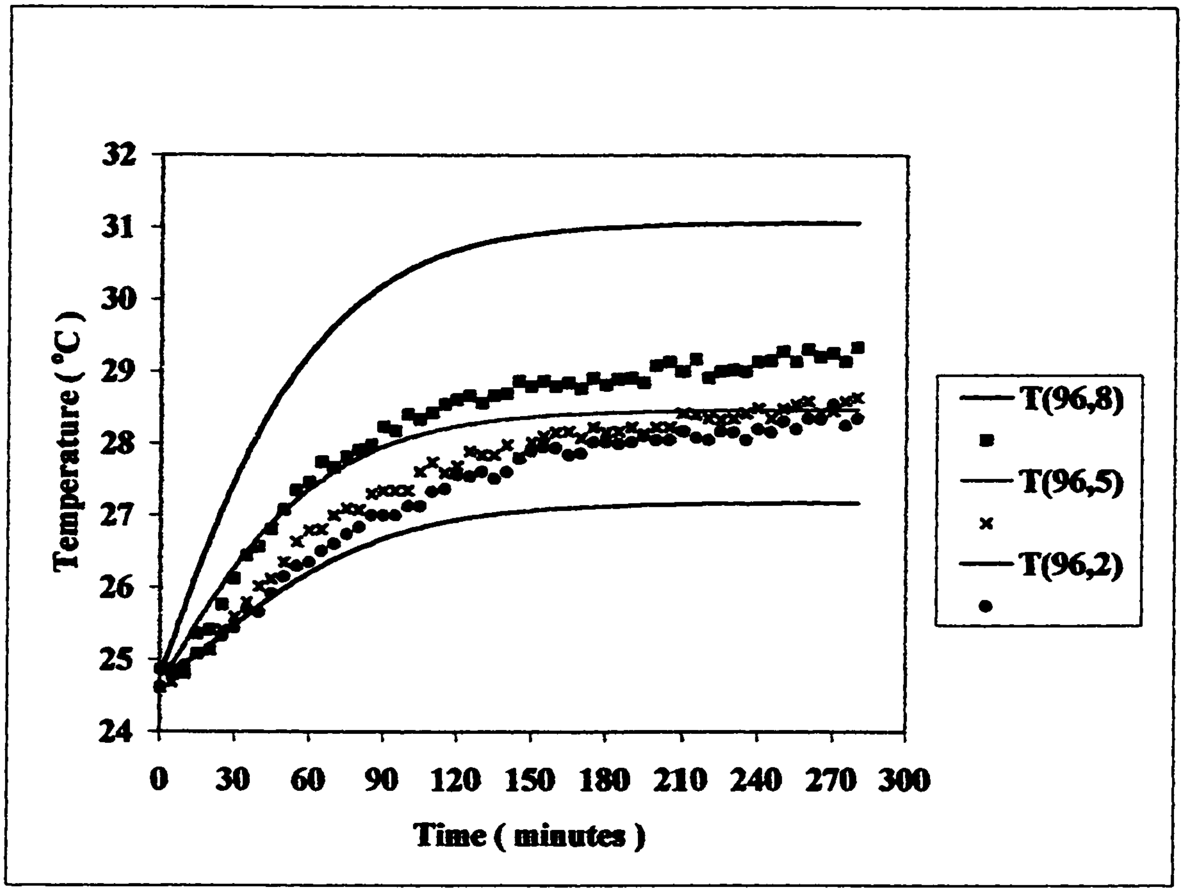


Figure 5.36: Measured and Predicted Radial Temperature Trend For large Rashig Ring, $d_p = 3.87$ cm, Run # 7 at x = 96 cm, Re = 672.6, $Q_w = 179.2$ W/M^2.

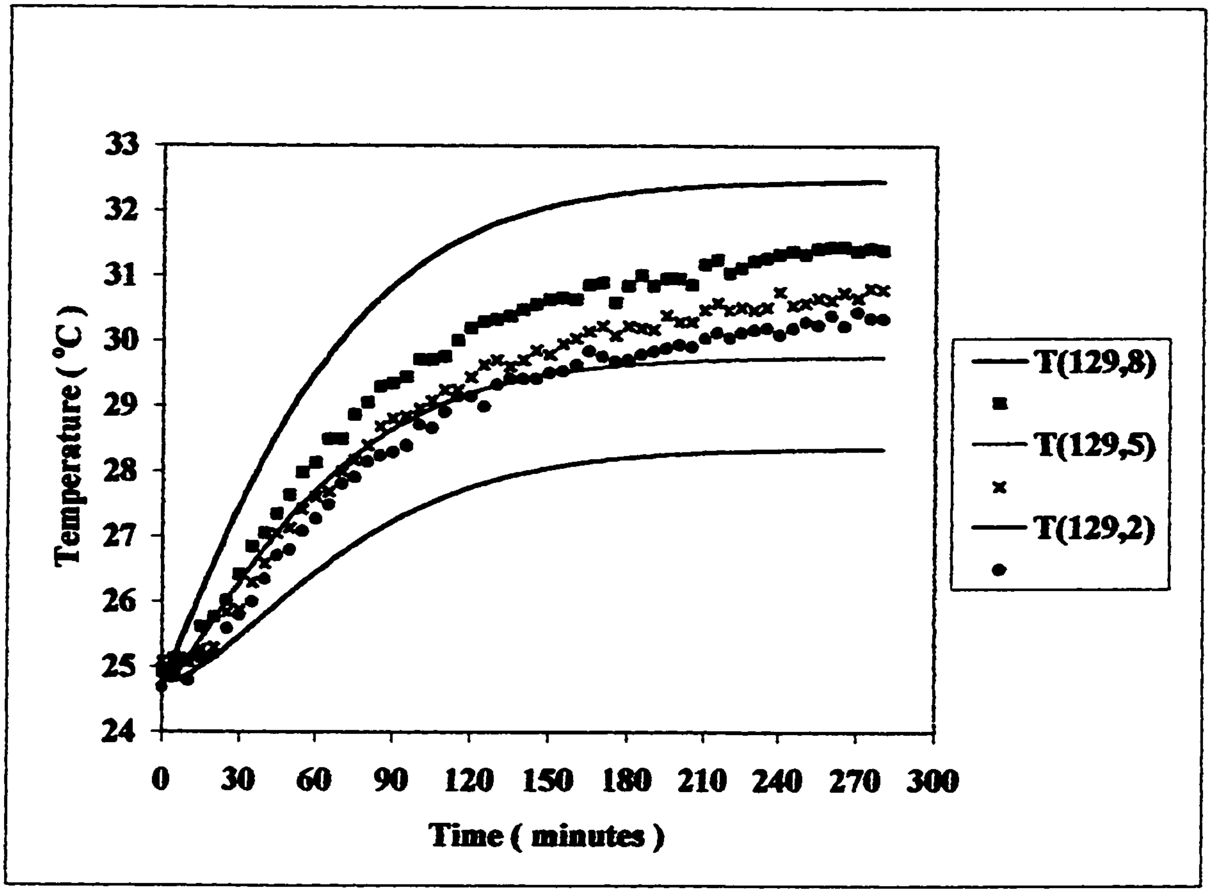


Figure 5.37: Measured and Predicted Radial Temperature Trend For large Rashig Ring, $d_p = 3.87$ cm, Run # 7 at x = 129 cm, Re = 672.6, $Q_w = 179.2$ W/m^2.

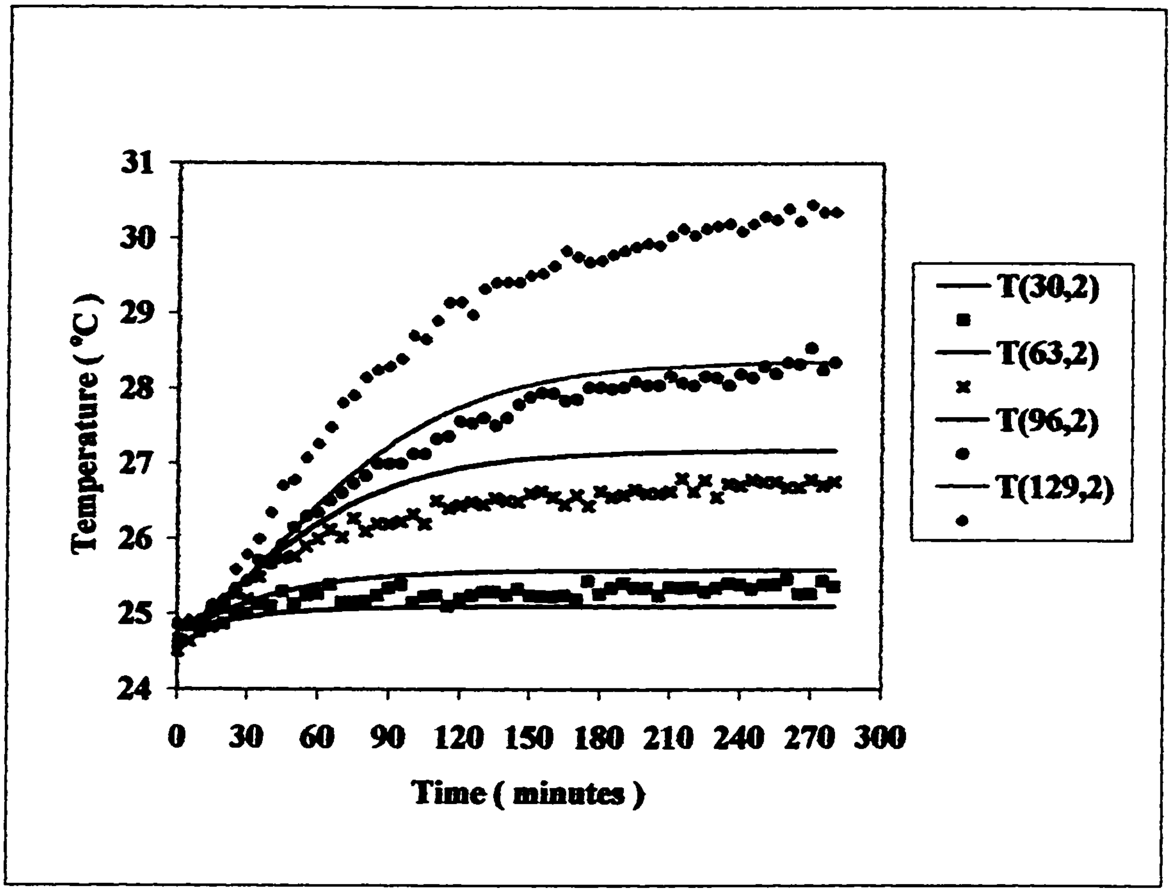


Figure 5.38: Measured and Predicted Axial Temperature Trend For Large Rashig Ring, d_p = 3.87 cm, Run # 7 at y = 2 cm, Re = 672.6, Q_w = 179.2 W/m^2.

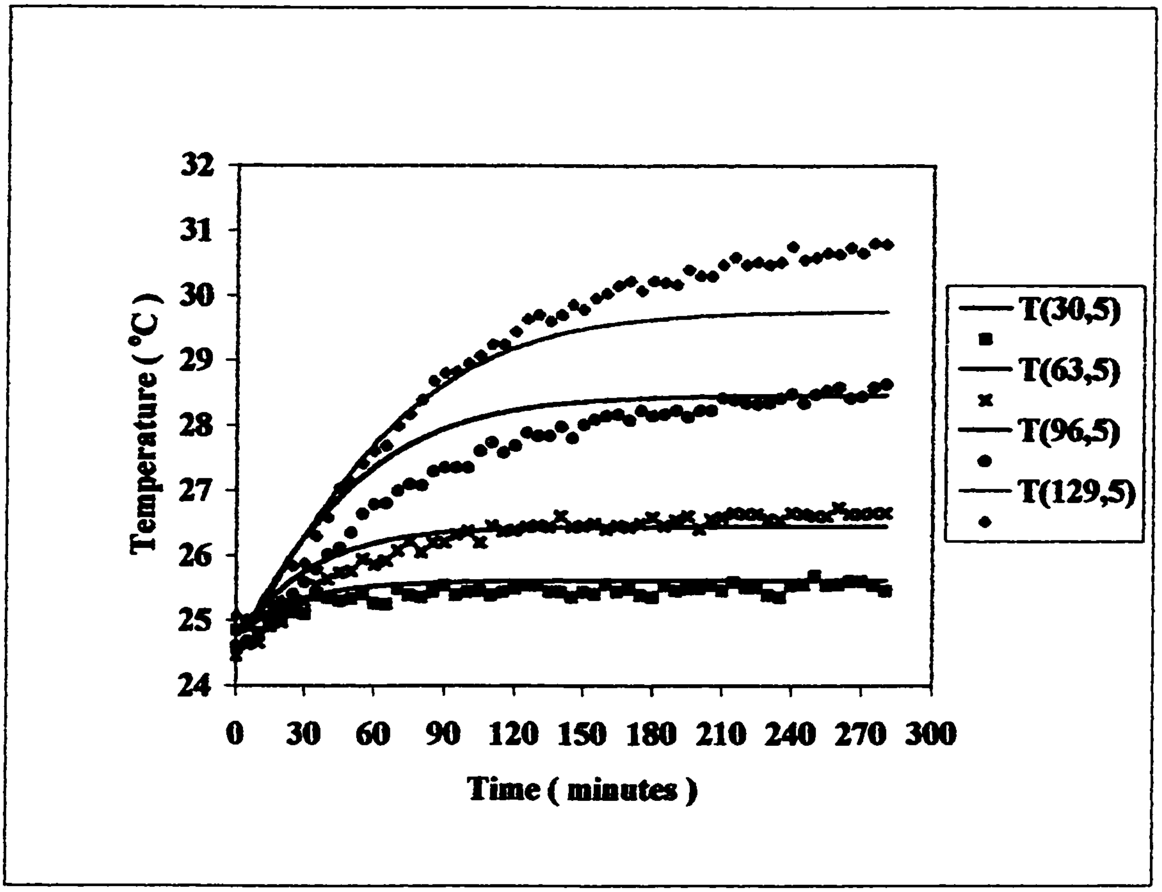


Figure 5.39: Measured and Predicted Axial Temperature Trend For Large Rashig Ring, d_p = 3.87 cm, Run # 7 at y = 5 cm, Re = 672.6, Q_w = 179.2 W/m^2.

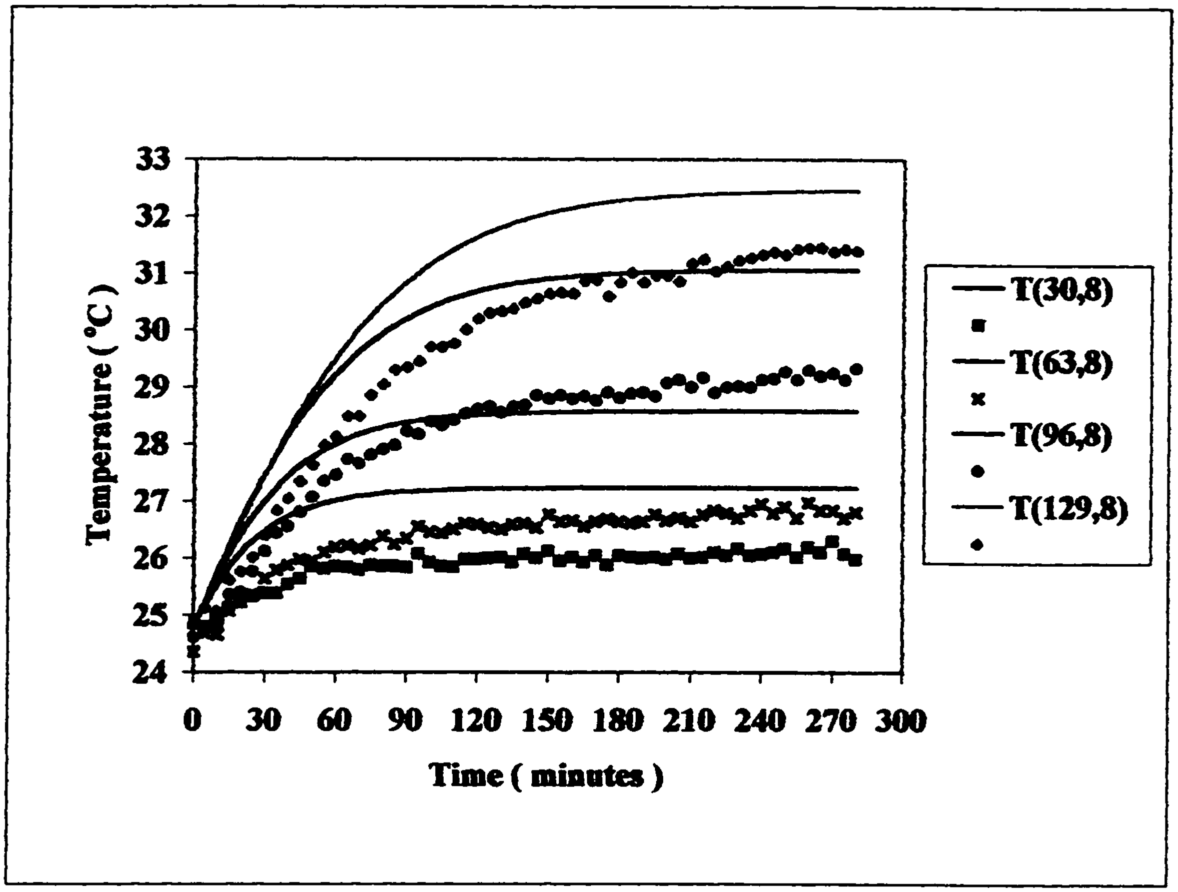


Figure 5.40: Measured and Predicted Axial Temperature Trend For Large Rashig Ring, d_p = 3.87 cm, Run # 7 at y = 8 cm, Re = 672.6, Q_w = 179.2 W/m^2.

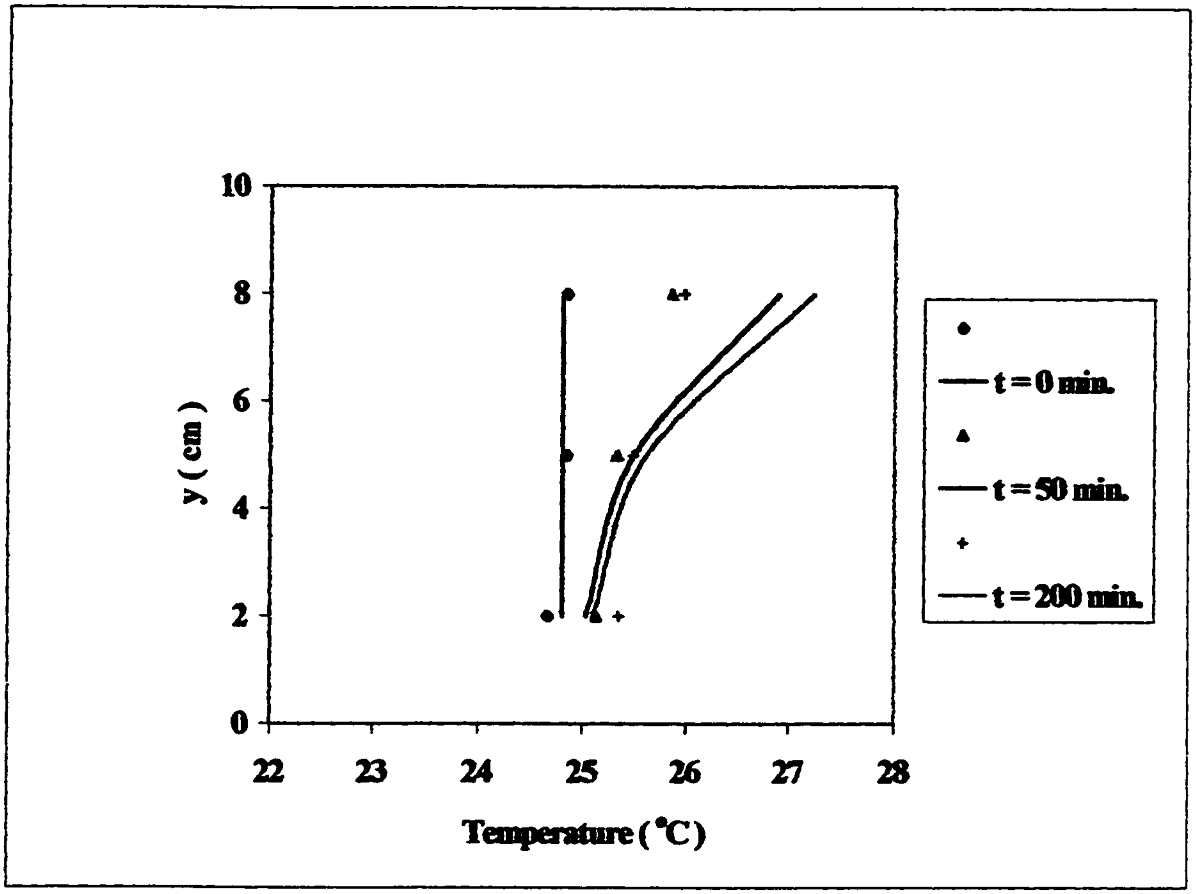


Figure 5.41: Measured and Predicted Radial Temperature Trend For Large Rashig Ring, d_p = 3.87 cm, Run # 2 at x= 30 cm, Re = 672.6, Q_w = 179.2 W/M^2.

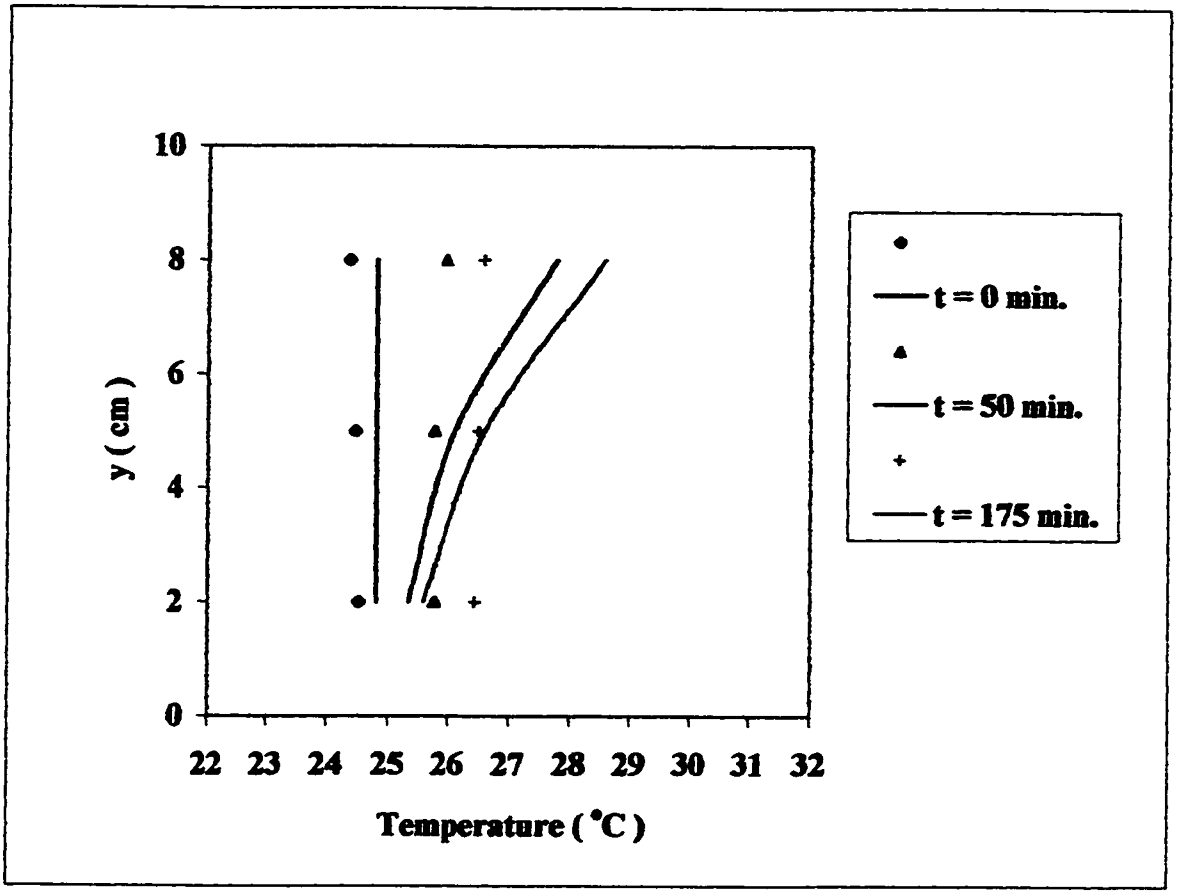


Figure 5.42: Measured and Predicted Radial Temperature Trend For Large Rashig Ring, $d_p = 3.87$ cm, Run # 2 at x = 63 cm, Re = 672.6, $Q_w = 179.2$ W/M^2.

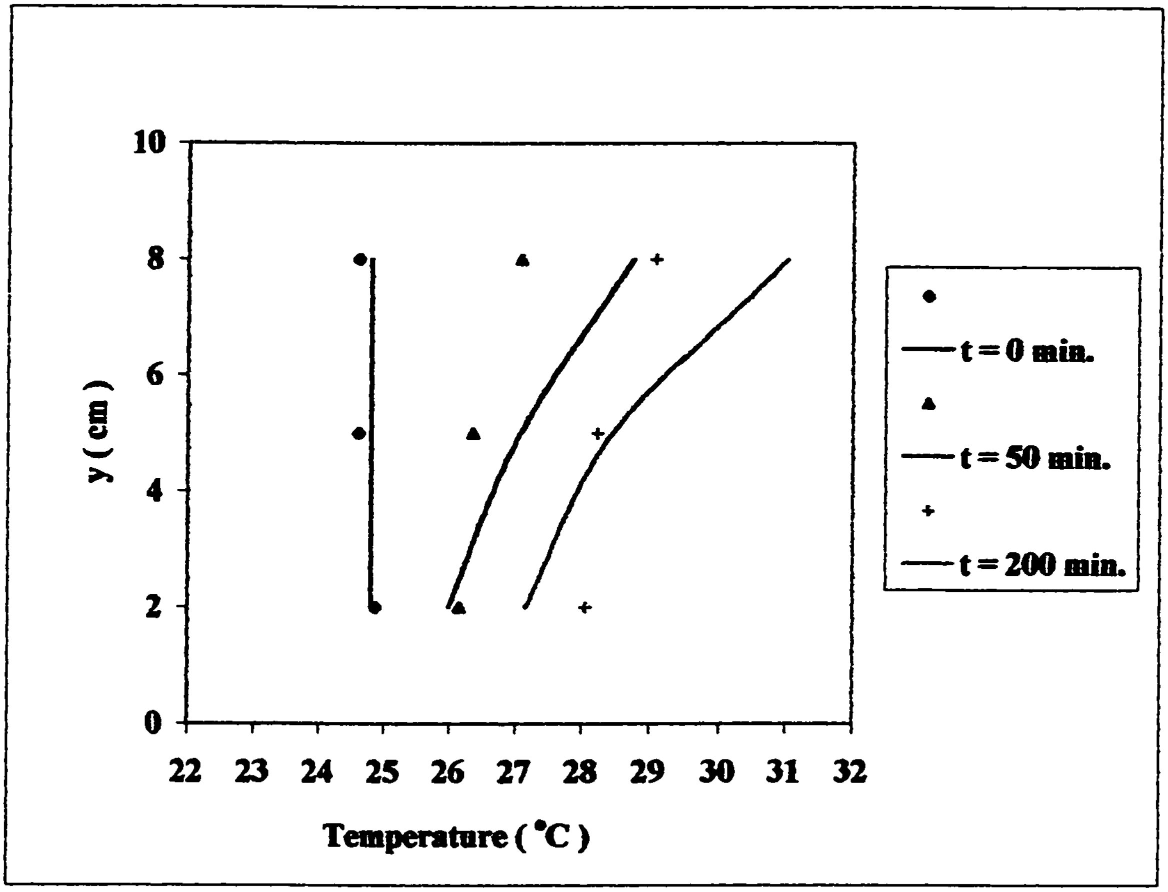


Figure 5.43: Measured and Predicted Radial Temperature Trend For Large Rashig Ring, d_p = 3.87 cm, Run # 2 at x= 96 cm, Re = 672.6, Q_w = 179.2 W/m^2.

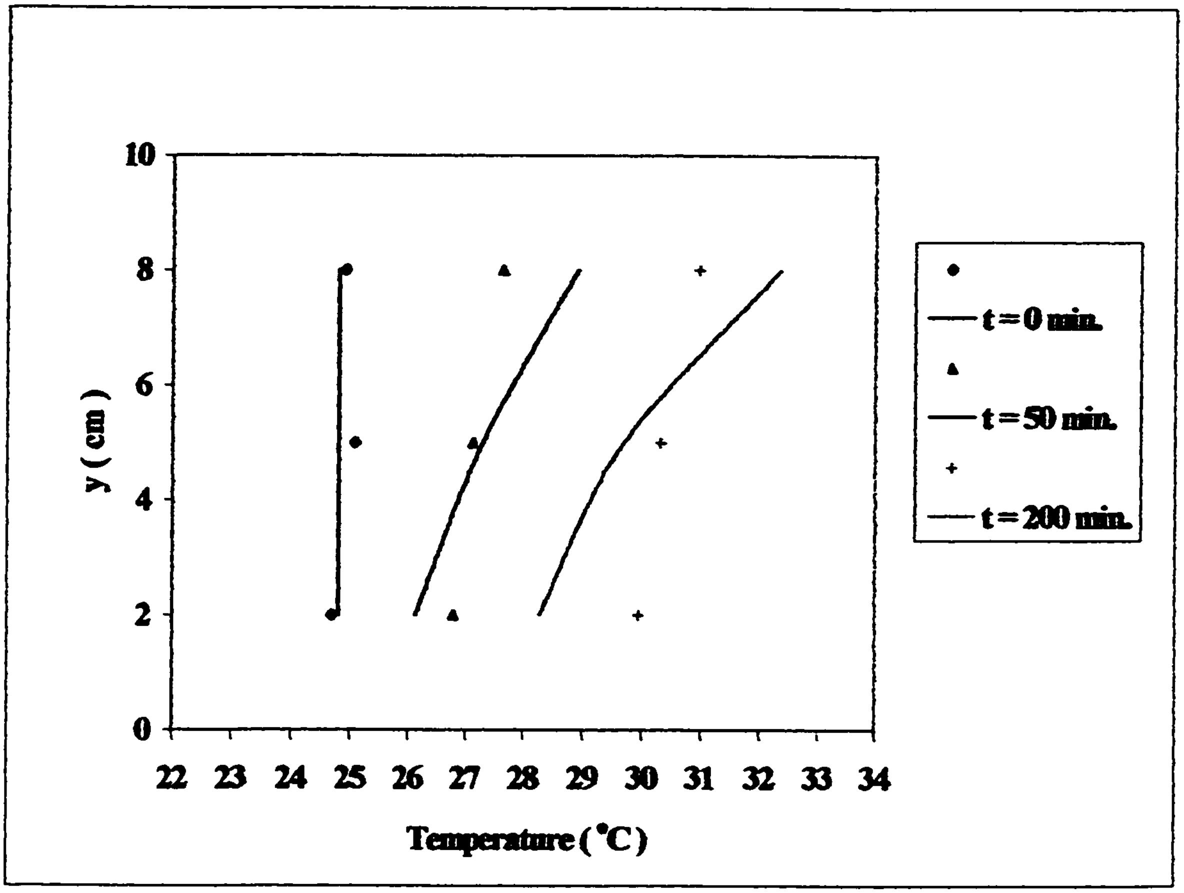


Figure 5.44: Measured and Predicted Radial Temperature Trend For Large Rashig Ring, d_p = 3.87 cm, Run # 2 at x = 129 cm, Re = 672.6, Q_w = 179.2 W/m^2.

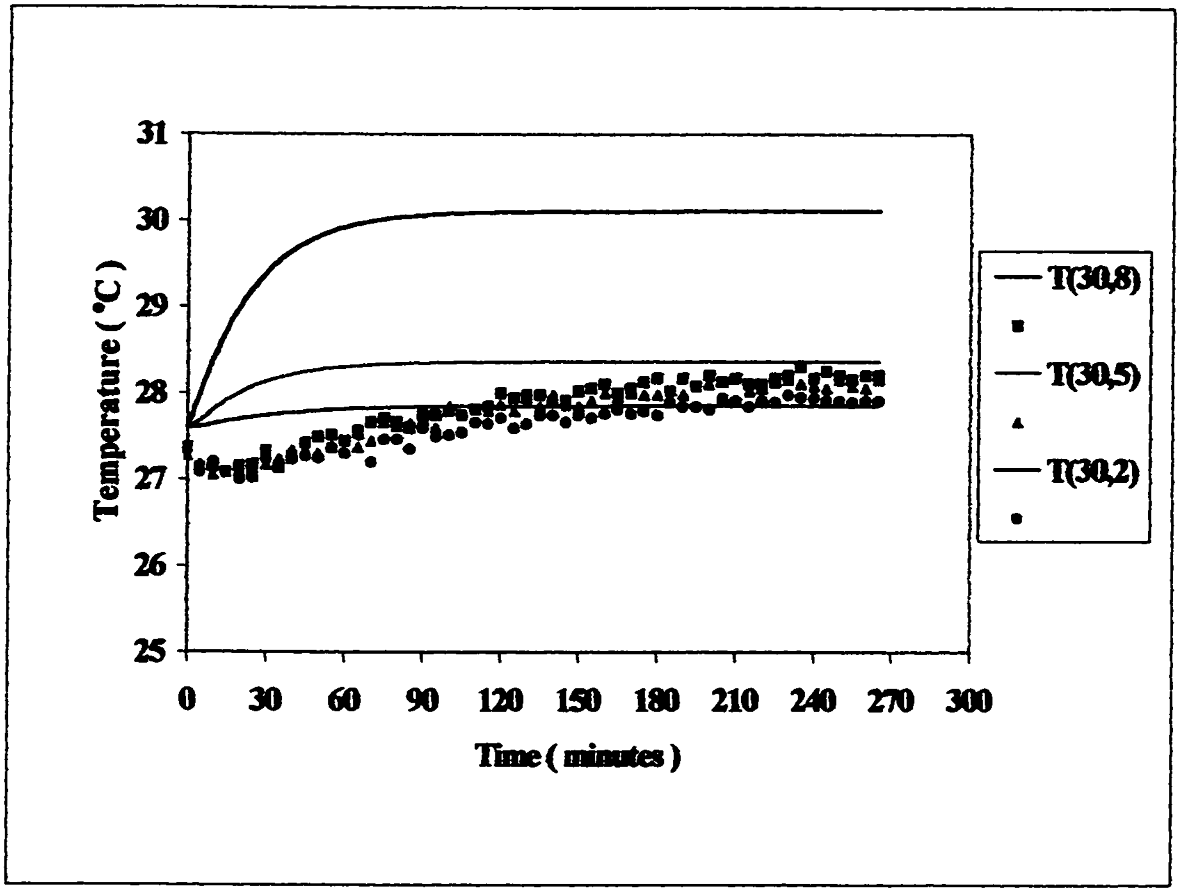


Figure 5.45: Measured and Predicted Radial Temperature Trend For Small Rashig Ring, $d_p = 3.27$ cm, Run # 7 at x = 30 cm, Re = 606.8, $Q_w = 179.2$ W/m^2.

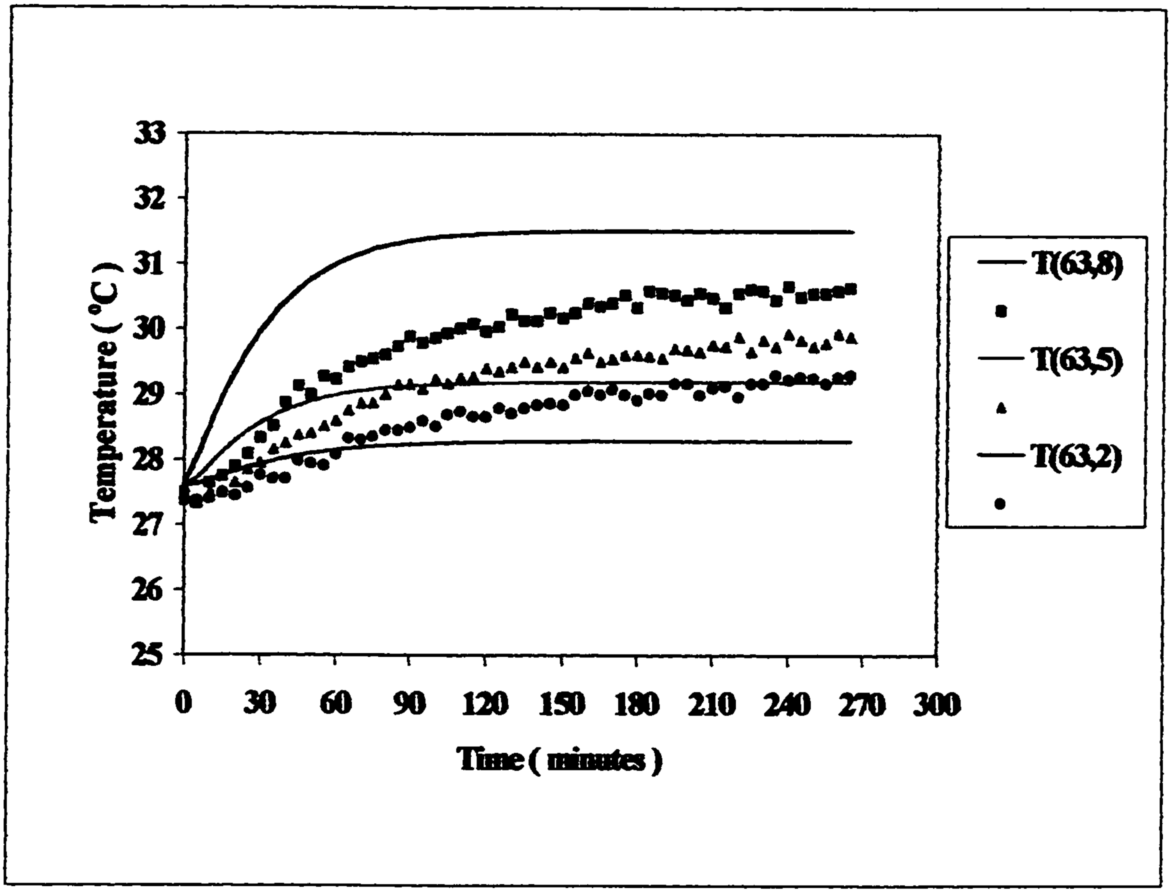


Figure 5.46: Measured and Predicted Radial Temperature Trend For Small Rashing Ring, $d_p = 3.27$ cm, Run # 7 at x = 63 cm, Re = 606.8, $Q_w = 179.2$ W/m^2.

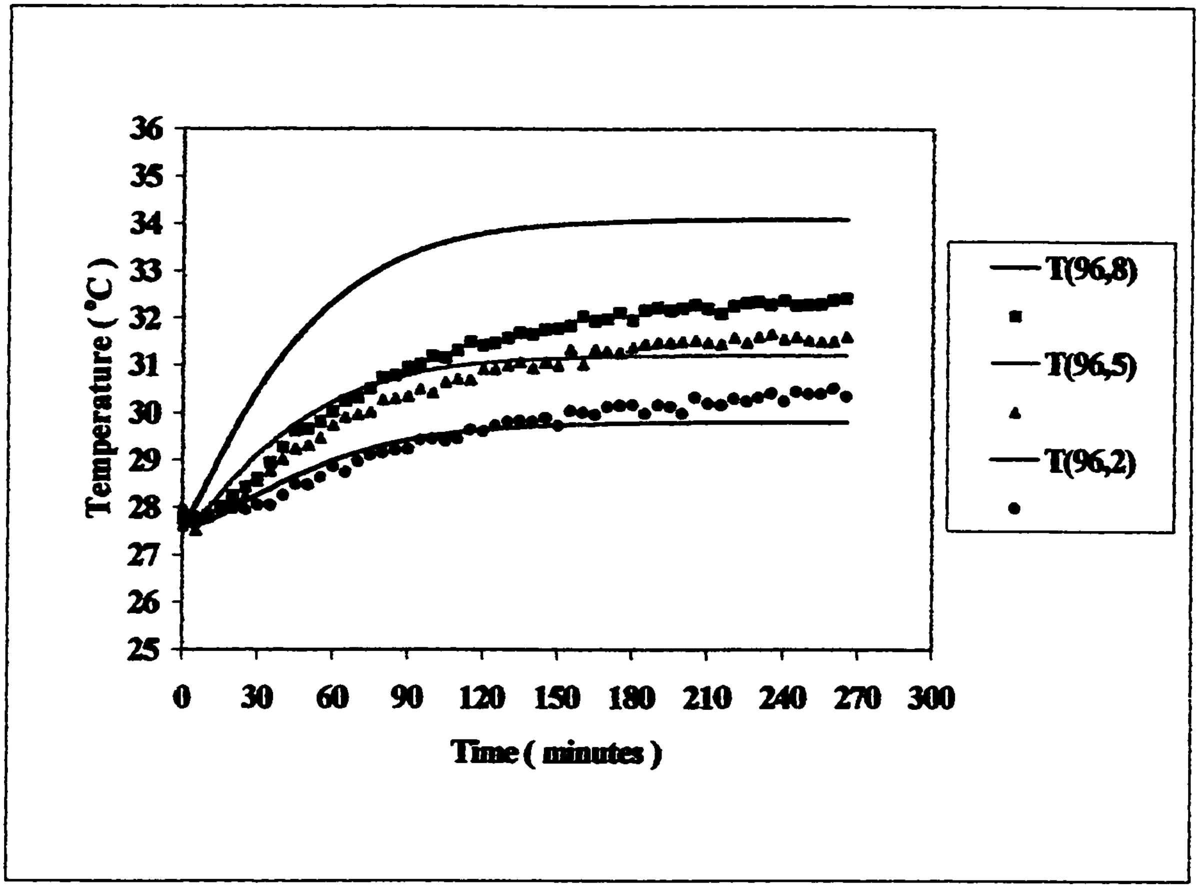


Figure 5.47: Measured and Predicted Radial Temperature Trend For Small Rashing Ring, d_p = 3.27 cm, Run # 7 at x = 96 cm, Re = 606.8, Q_w = 179.2 W/m^2.

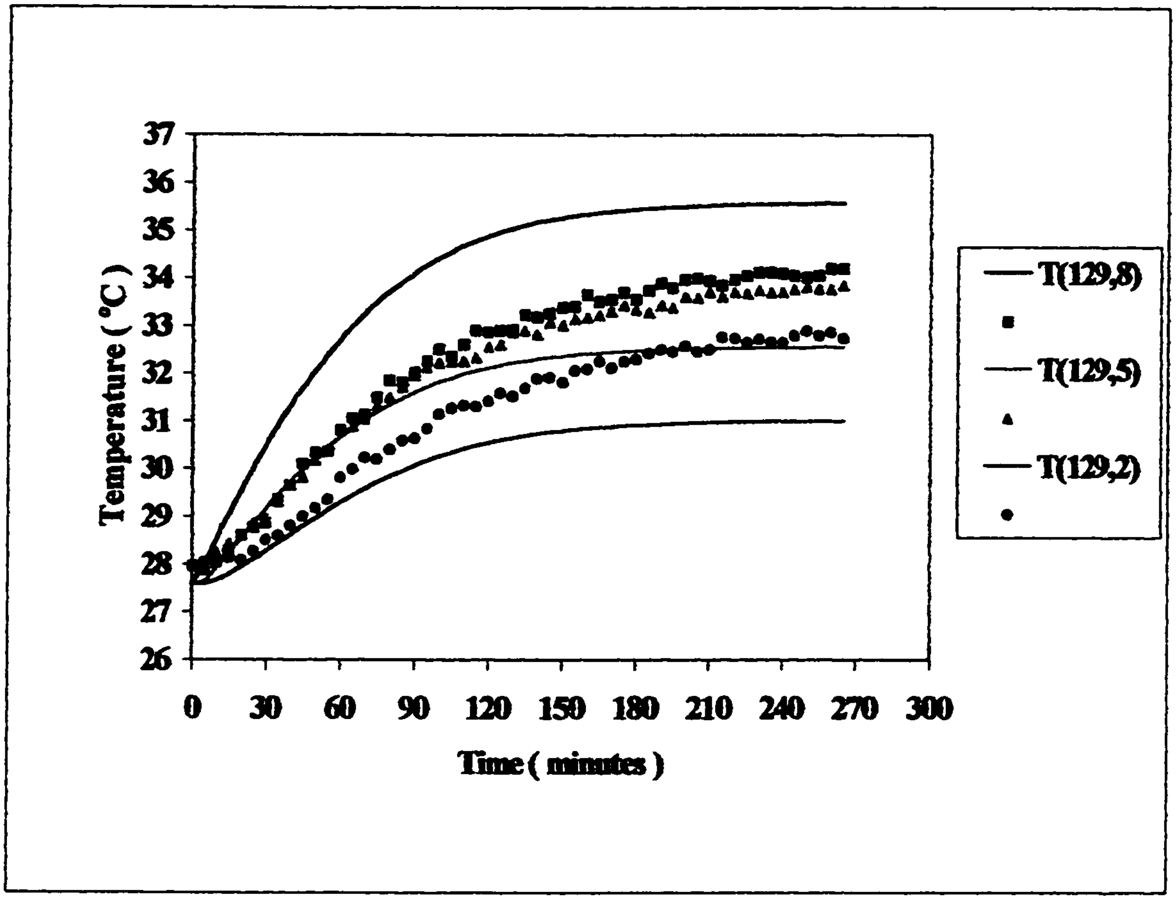


Figure 5.48: Measured and Predicted Radial Temperature Trend For Small Rashing Ring, d_p = 3.27 cm, Run # 7 at x = 129 cm, Re = 606.8, Q_w = 179.2 W/m^2.

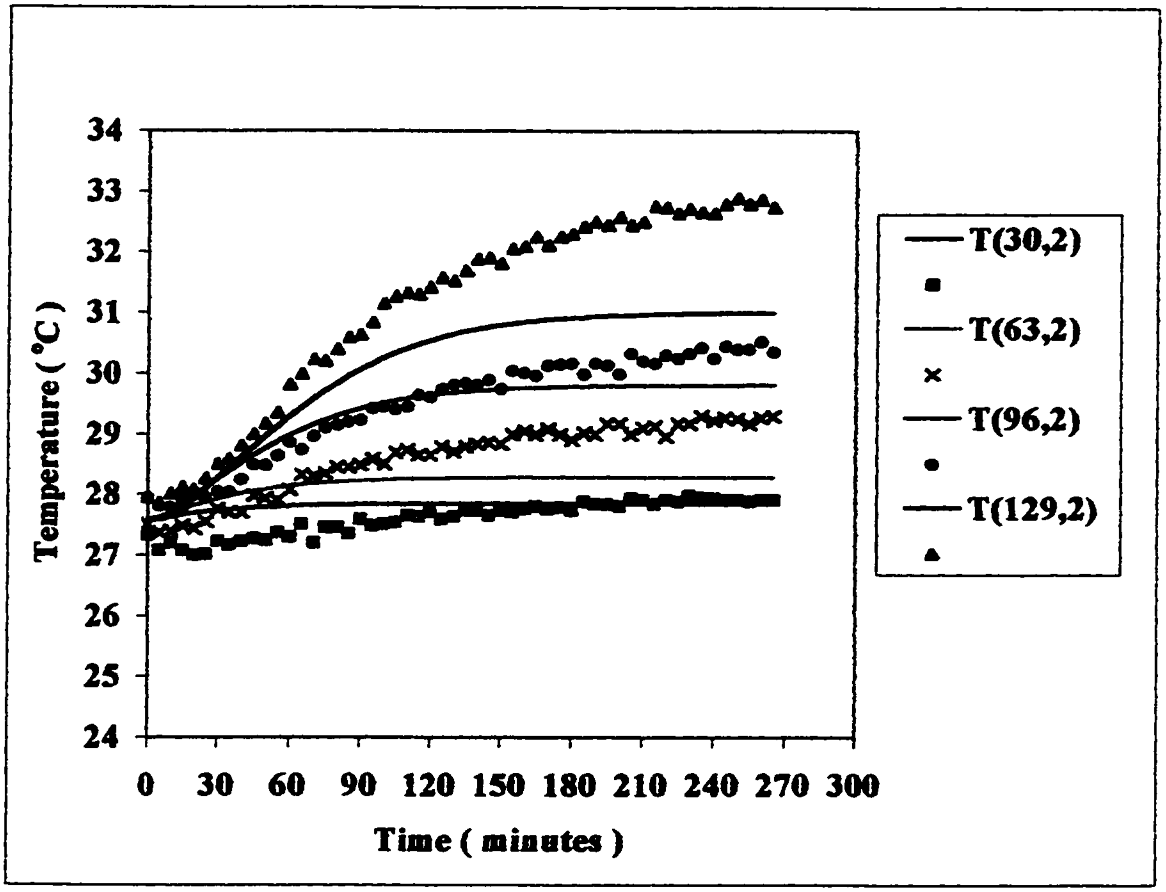


Figure 5.49: Measured and Predicted Axial Temperature Trend For Small Rashig Ring, d_p = 3.27 cm, Run # 7 at y = 2 cm, Re = 606.8, Q_w = 179.2 W/m^2.

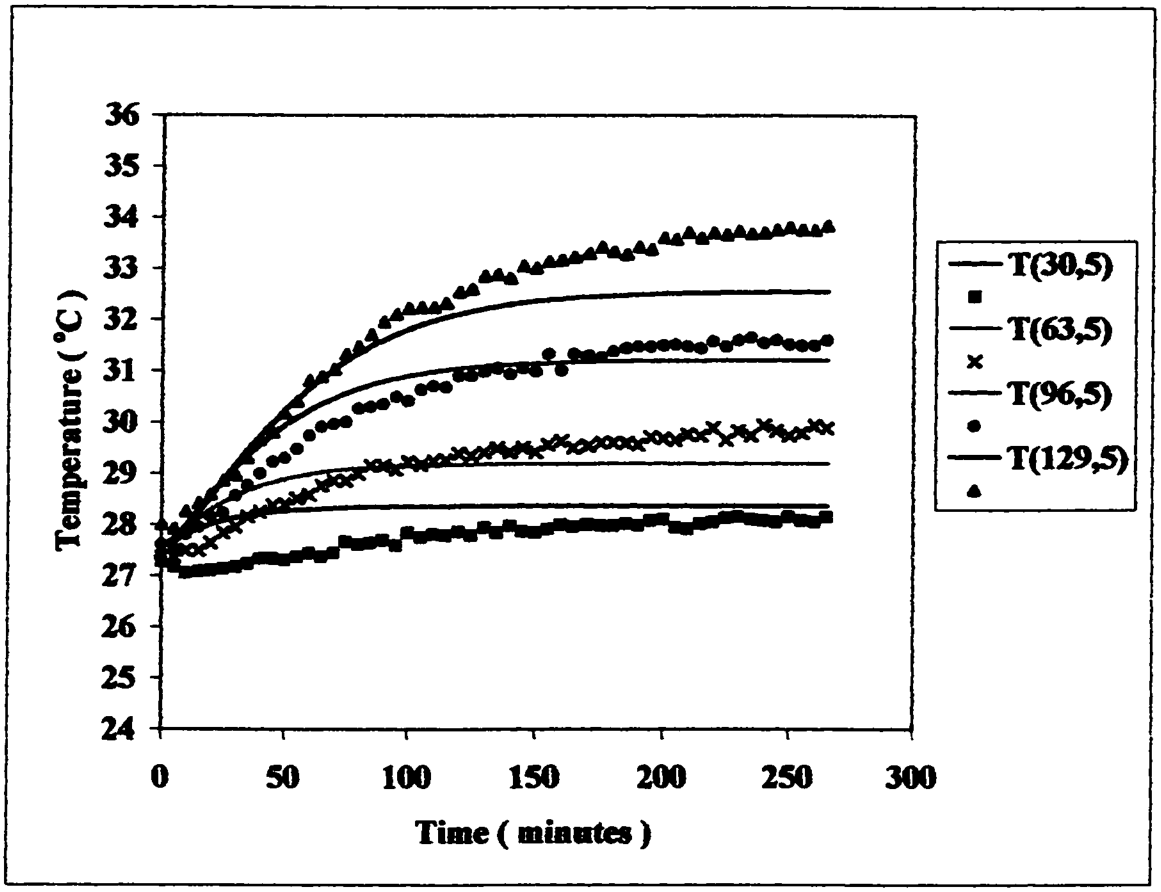


Figure 5.50: Measured and Predicted Axial Temperature Trend For Small Rashig Ring, d_p = 3.27 cm, Run # 7 at y = 5 cm, Re = 606.8, Q_w = 179.2 W/m^2.

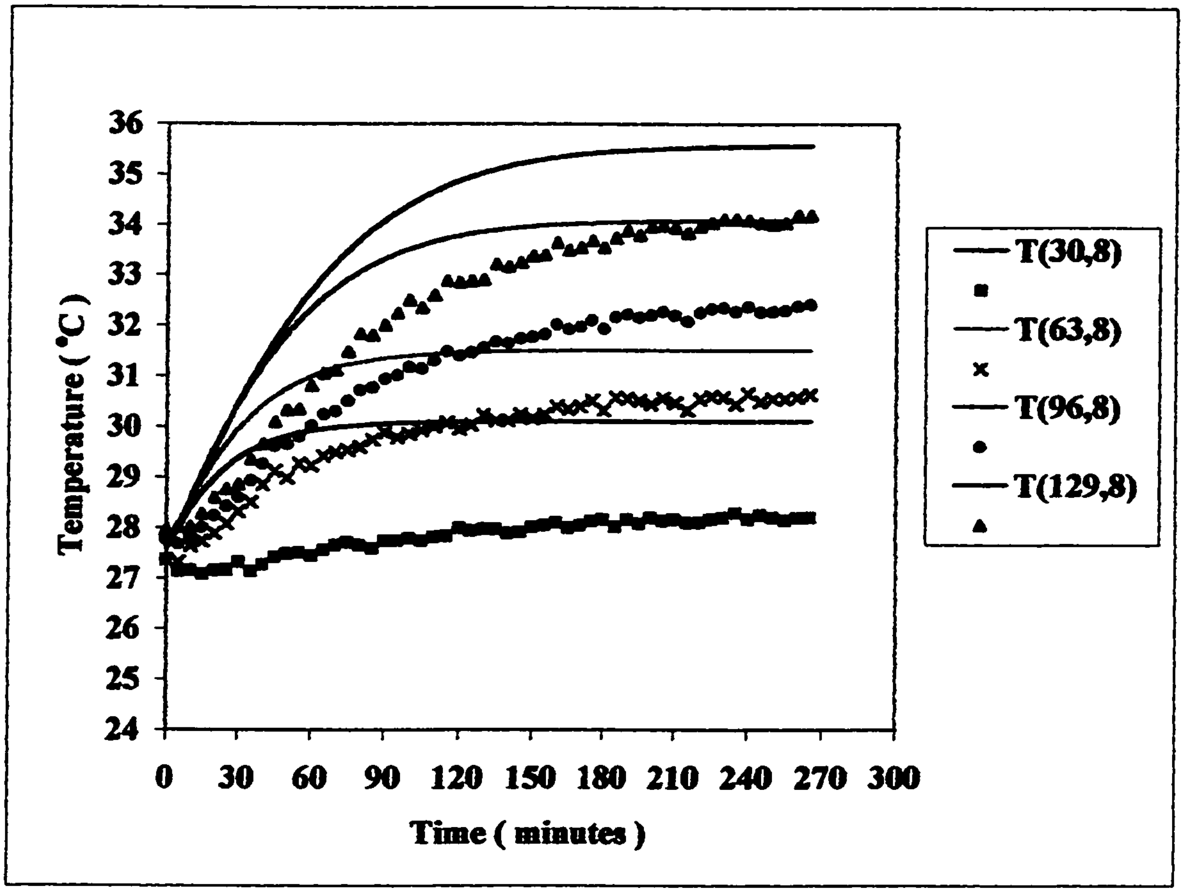


Figure 5.51: Measured and Predicted Axial Temperature Trend For Small Rashig Ring, d_p = 3.27 cm, Run # 7 at y = 8 cm, Re = 606.8, Q_w = 179.2 W/m^2.

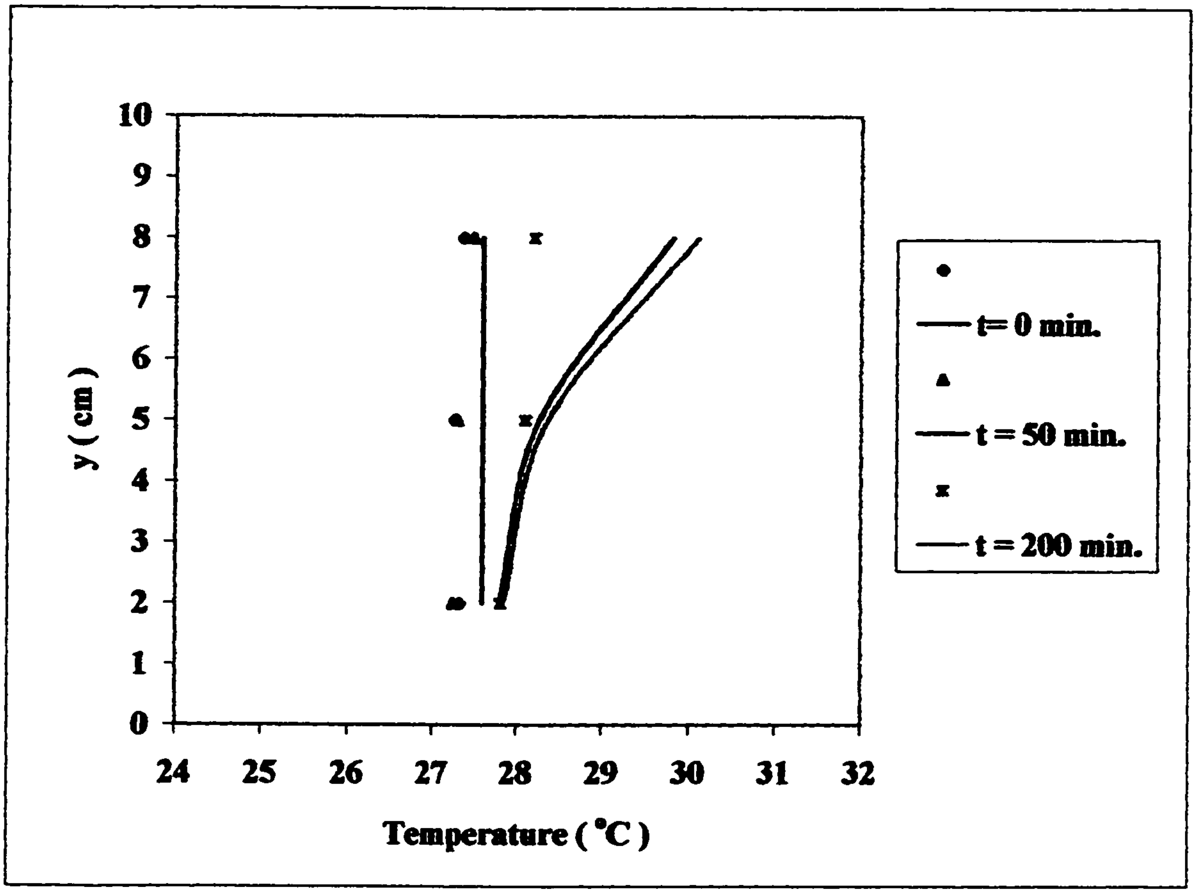


Figure 5.52: Measured and Predicted Radial Temperature Trend For Small Rashig Ring, d_p = 3.27 cm, Run # 7 at x= 30 cm, Re = 606.8 Q_w = 179.2 W/m^2.

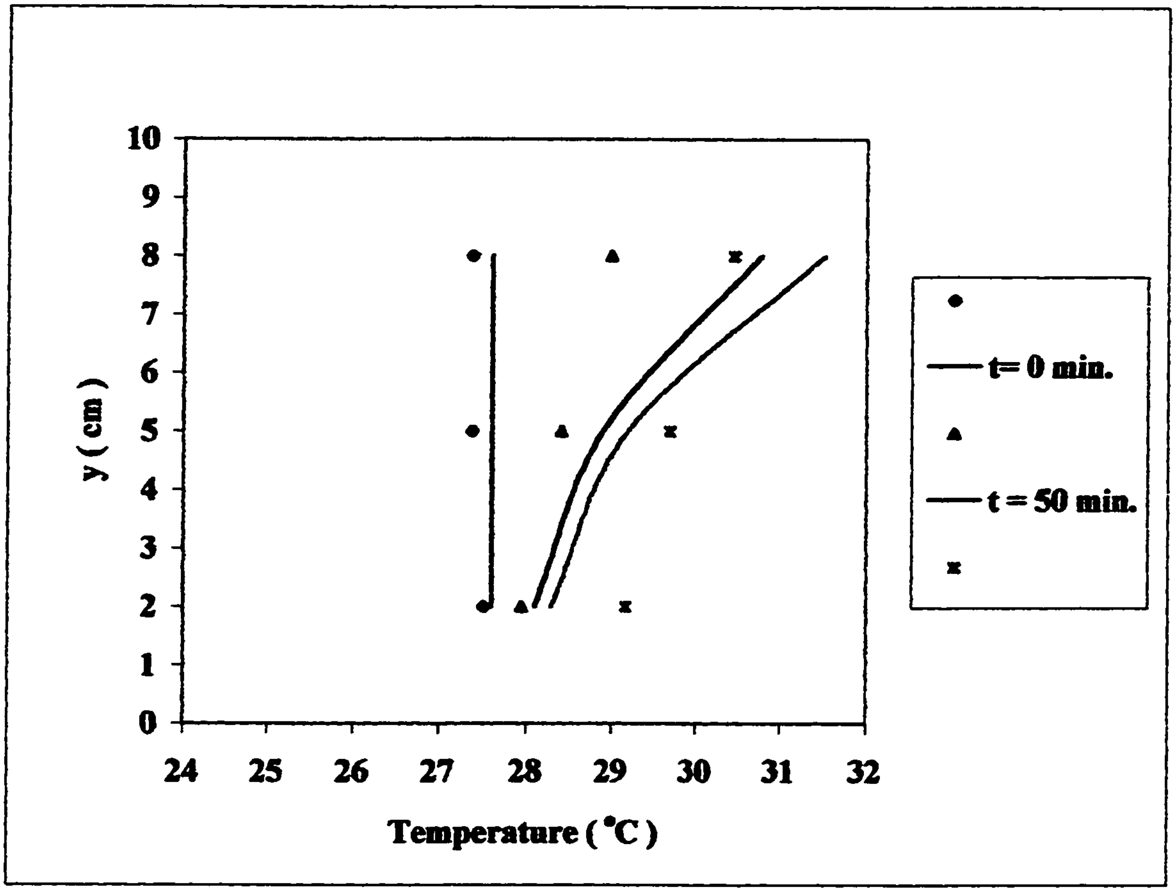


Figure 5.53: Measured and Predicted Radial Temperature Trend For Small Rashig Ring, d_p = 3.27 cm, Run # 7 at x= 63 cm, Re = 606.8 Q_w = 179.2 W/m^2.

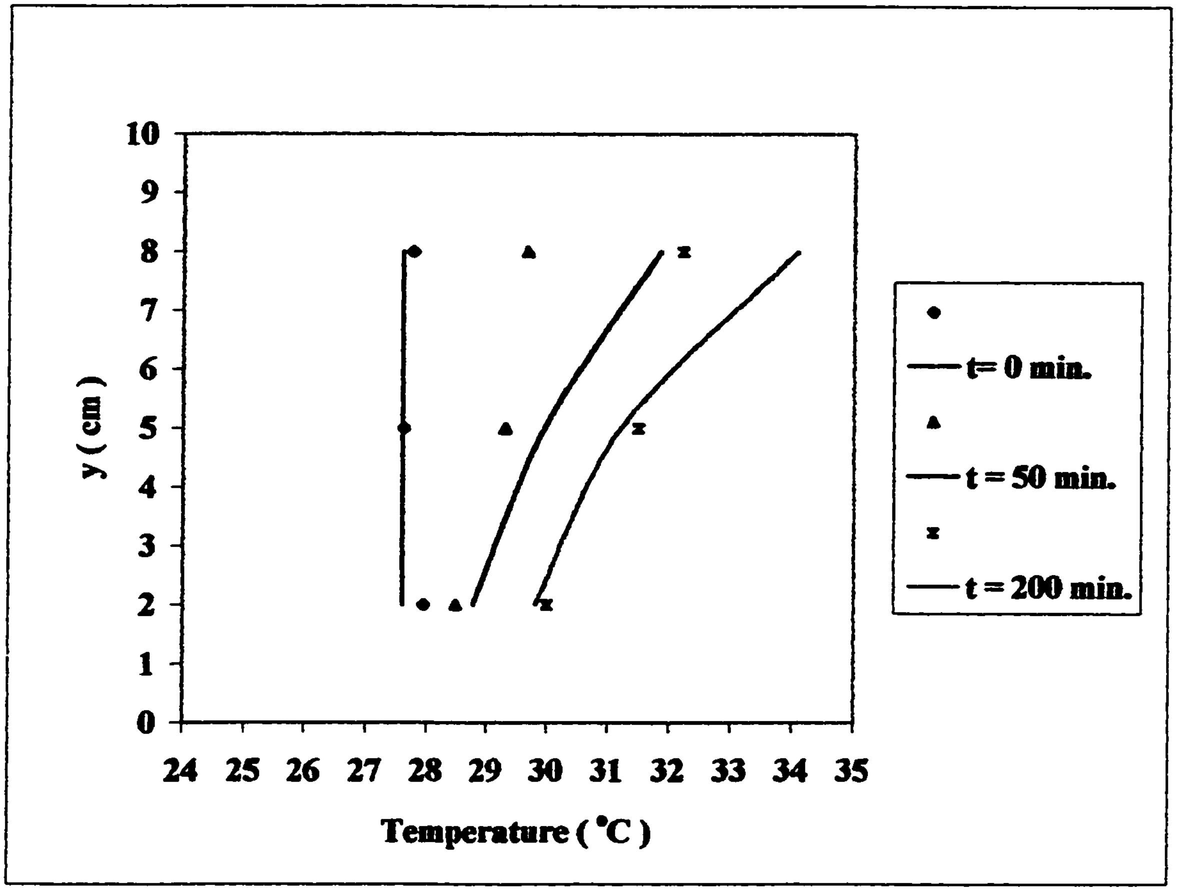


Figure 5.54: Measured and Predicted Radial Temperature Trend For Small Rashig Ring, d_p = 3.27 cm, Run # 7 at x= 96 cm, Re = 606.8 Q_w = 179.2 W/m^2.

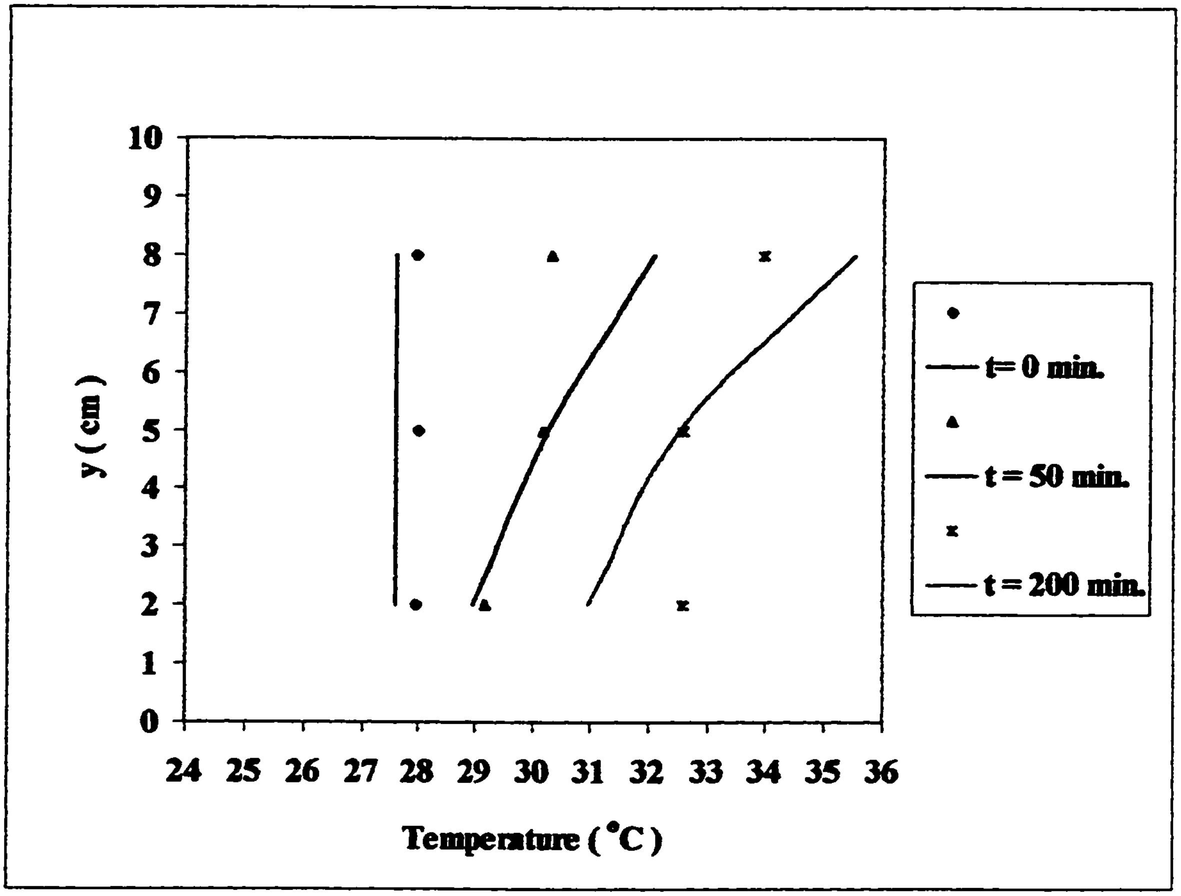


Figure 5.55: Measured and Predicted Radial Temperature Trend For Small Rashig Ring, $d_p = 3.27$ cm, Run # 7 at x= 129 cm, Re = 606.8 $Q_w = 179.2$ W/m^2.

Table 5.1: Comparison between Predicted and Measured Temperatures for Large Sphere Run # 7, Temperature in °C and Time in minutes.

Time	T(30,8) Predicted	T(30,8) Measured	% Error	T(30,5) Predicted	T(30,5) Measured	% Error	T(30,2) Predicted	T(30,2) Measured	% Error
0	25.000	24.9	0.4	25.000	24.85	0.6	25.000	24.85	0.6
5	25.357	25.08	1.1	25.134	24.92	0.9	25.038	24.87	0.7
10	25.661	25.25	1.6	25.248	25.15	0.4	25.075	25	0.3
15	25.919	25.36	2.2	25.344	25.17	0.7	25.109	24.92	0.8
20	26.136	25.25	3.5	25.425	25.39	0.1	25.140	25.1	0.2
25	26.318	25.41	3.6	25.493	25.36	0.5	25.169	25.08	0.4
30	26.471	25.51	3.8	25.551	25.46	0.4	25.195	24.98	0.9
35	26.598	25.66	3.7	25.600	25.36	0.9	25.218	25.17	0.2
40	26.705	25.81	3.5	25.641	25.51	0.5	25.239	25.15	0.4
45	26.794	25.84	3.7	25.676	25.59	0.3	25.258	25.2	0.2
50	26.868	25.88	3.8	25.705	25.49	0.8	25.275	25.3	0.1
55	26.930	25.76	4.5	25.730	25.56	0.7	25.290	25.23	0.2
60	26.981	25.9	4.2	25.751	25.66	0.4	25.304	25.23	0.3
65	27.025	26.05	3.7	25.769	25.56	0.8	25.315	25.27	0.2
70	27.061	25.98	4.2	25.785	25.64	0.6	25.326	25.39	0.3
75	27.091	25.9	4.6	25.798	25.56	0.9	25.335	25.36	0.1
80	27.116	26	4.3	25.809	25.71	0.4	25.343	25.46	0.5
85	27.138	26.15	3.8	25.818	25.66	0.6	25.350	25.41	0.2
90	27.156	26.23	3.5	25.826	25.69	0.5	25.357	25.2	0.6
95	27.171	26.1	4.1	25.833	25.76	0.3	25.362	25.41	0.2
100	27.183	26.08	4.2	25.839	25.88	0.2	25.367	25.39	0.1
105	27.194	26.17	3.9	25.844	25.64	0.8	25.372	25.49	0.5
110	27.203	26.12	4.1	25.848	25.69	0.6	25.375	25.44	0.3
115	27.211	26.1	4.3	25.852	25.9	0.2	25.379	25.23	0.6
120	27.217	26	4.7	25.855	25.71	0.6	25.382	25.36	0.1
125	27.223	26.05	4.5	25.858	25.76	0.4	25.384	25.56	0.7
130	27.227	26.15	4.1	25.860	25.86	0.0	25.386	25.41	0.1
135	27.231	26.23	3.8	25.862	25.92	0.2	25.388	25.39	0.0
140	27.235	26.27	3.7	25.864	25.74	0.5	25.390	25.49	0.4
145	27.237	26.17	4.1	25.865	25.84	0.1	25.391	25.49	0.4
150	27.240	26.3	3.6	25.867	25.9	0.1	25.393	25.46	0.3
155	27.242	26.2	4.0	25.868	25.66	0.8	25.394	25.56	0.7
160	27.244	26.17	4.1	25.869	25.84	0.1	25.395	25.54	0.6
165	27.245	26.35	3.4	25.870	25.81	0.2	25.396	25.41	0.1
170	27.247	26.23	3.9	25.870	25.92	0.2	25.397	25.49	0.4
175	27.248	26.27	3.7	25.871	25.79	0.3	25.397	25.41	0.1
180	27.249	26.25	3.8	25.871	25.86	0.0	25.398	25.51	0.4
185	27.249	26.33	3.5	25.872	25.88	0.0	25.398	25.51	0.4
190	27.250	26.3	3.6	25.872	25.92	0.2	25.399	25.54	0.6

Table 5.1 (continued).

TIME	T(63,8) Predicted	T(63,8) Measured	% Error	T(63,5) Predicted	T(63,5) Measured	% Error	T(63,2) Predicted	T(63,2) Measured	% Error
0	25.000	24.85	0.6	25.000	24.76	1.0	25.000	24.95	0.2
5	25.422	25.13	1.2	25.207	25.02	0.7	25.071	24.98	0.4
10	25.800	25.39	1.6	25.390	24.95	1.8	25.140	25	0.6
15	26.137	25.61	2.1	25.553	25.13	1.7	25.208	25.08	0.5
20	26.438	25.59	3.3	25.697	25.3	1.6	25.273	25.25	0.1
25	26.703	25.92	3.0	25.824	25.33	1.9	25.335	25.17	0.7
30	26.937	25.98	3.7	25.935	25.36	2.3	25.393	25.23	0.6
35	27.142	26.05	4.2	26.033	25.41	2.5	25.446	25.27	0.7
40	27.322	26.35	3.7	26.119	25.46	2.6	25.496	25.35	0.6
45	27.479	26.41	4.0	26.194	25.49	2.8	25.542	25.54	0.0
50	27.615	26.51	4.2	26.259	25.59	2.6	25.583	25.39	0.8
55	27.733	26.54	4.5	26.317	25.76	2.2	25.621	25.51	0.4
60	27.836	26.59	4.7	26.366	25.66	2.8	25.655	25.66	0.0
65	27.924	26.64	4.8	26.410	25.61	3.1	25.686	25.46	0.9
70	28.001	26.74	4.7	26.447	25.79	2.5	25.714	25.49	0.9
75	28.067	26.69	5.2	26.480	25.66	3.2	25.739	25.56	0.7
80	28.124	26.74	5.2	26.508	25.81	2.7	25.761	25.66	0.4
85	28.174	26.74	5.4	26.533	25.9	2.4	25.781	25.66	0.5
90	28.216	26.81	5.2	26.555	25.84	2.8	25.799	25.69	0.4
95	28.252	26.89	5.1	26.573	25.81	3.0	25.815	25.56	1.0
100	28.284	26.81	5.5	26.589	25.92	2.6	25.829	25.69	0.5
105	28.311	26.91	5.2	26.603	25.84	3.0	25.841	25.69	0.6
110	28.334	27.08	4.6	26.616	25.92	2.7	25.852	25.54	1.2
115	28.354	26.84	5.6	26.626	25.9	2.8	25.862	25.61	1.0
120	28.371	26.98	5.2	26.636	25.71	3.6	25.871	25.76	0.4
125	28.386	27.02	5.1	26.644	25.95	2.7	25.878	25.66	0.9
130	28.399	26.98	5.3	26.650	26	2.5	25.885	25.81	0.3
135	28.410	27	5.2	26.657	25.92	2.8	25.891	25.69	0.8
140	28.420	26.91	5.6	26.662	25.88	3.0	25.896	25.74	0.6
145	28.428	26.95	5.5	26.666	25.88	3.0	25.901	25.74	0.6
150	28.435	26.98	5.4	26.670	25.95	2.8	25.905	25.76	0.6
155	28.441	27.02	5.3	26.674	26.05	2.4	25.909	25.86	0.2
160	28.446	27.1	5.0	26.677	25.92	2.9	25.912	25.79	0.5
165	28.451	27.08	5.1	26.679	26.05	2.4	25.915	25.76	0.6
170	28.455	27.1	5.0	26.682	26.02	2.5	25.917	25.84	0.3
175	28.458	27.08	5.1	26.684	26.12	2.2	25.919	25.79	0.5
180	28.461	27.17	4.8	26.685	25.95	2.8	25.921	25.76	0.6
185	28.463	27.2	4.6	26.687	25.92	3.0	25.923	26.02	0.4
190	28.466	27.25	4.5	26.688	25.98	2.7	25.924	25.92	0.0

Table 5.1 (continued).

Time	T(96,8) Predicted	T(96,8) Measured	% Error	T(96,5) Predicted	T(96,5) Measured	% Error	T(96,2) Predicted	T(96,2) Measured	% Error
0	25.000	25	0.0	25.000	25	0.0	25.000	25.13	0.5
5	25.469	25.23	0.9	25.277	25.27	0.0	25.110	25.25	0.6
10	25.907	25.79	0.5	25.541	25.54	0.0	25.227	25.39	0.6
15	26.318	26.15	0.6	25.791	25.71	0.3	25.351	25.56	0.8
20	26.701	26.59	0.4	26.027	26.05	0.1	25.478	25.88	1.6
25	27.058	26.76	1.1	26.250	26.23	0.1	25.607	25.84	0.9
30	27.389	27.05	1.3	26.458	26.41	0.2	25.735	25.98	0.9
35	27.696	27.25	1.6	26.652	26.66	0.0	25.861	26.12	1.0
40	27.980	27.54	1.6	26.833	26.79	0.2	25.984	26.27	1.1
45	28.242	27.66	2.1	27.000	26.98	0.1	26.102	26.2	0.4
50	28.483	27.91	2.1	27.155	27.08	0.3	26.216	26.38	0.6
55	28.705	27.98	2.6	27.297	27.1	0.7	26.325	26.38	0.2
60	28.907	28.13	2.8	27.428	27.15	1.0	26.427	26.54	0.4
65	29.092	28.13	3.4	27.547	27.35	0.7	26.524	26.54	0.1
70	29.261	28.38	3.1	27.657	27.46	0.7	26.615	26.76	0.5
75	29.414	28.38	3.6	27.756	27.42	1.2	26.700	26.66	0.1
80	29.554	28.42	4.0	27.847	27.46	1.4	26.779	26.76	0.1
85	29.680	28.56	3.9	27.929	27.61	1.2	26.852	26.81	0.2
90	29.794	28.69	3.8	28.004	27.61	1.4	26.919	26.81	0.4
95	29.897	28.61	4.5	28.071	27.64	1.6	26.982	26.89	0.3
100	29.991	28.74	4.4	28.132	27.69	1.6	27.039	26.84	0.7
105	30.074	28.71	4.8	28.187	27.76	1.5	27.091	26.91	0.7
110	30.149	28.81	4.6	28.237	27.81	1.5	27.139	27	0.5
115	30.217	28.76	5.1	28.281	27.84	1.6	27.183	26.81	1.4
120	30.278	28.71	5.5	28.321	27.74	2.1	27.223	27.08	0.5
125	30.332	28.84	5.2	28.357	27.79	2.0	27.259	26.98	1.0
130	30.380	28.81	5.5	28.389	27.91	1.7	27.292	27.08	0.8
135	30.424	28.79	5.7	28.418	27.94	1.7	27.321	26.98	1.3
140	30.462	28.99	5.1	28.444	27.91	1.9	27.348	27.08	1.0
145	30.497	28.89	5.6	28.467	27.95	1.8	27.372	27.15	0.8
150	30.528	29.1	4.9	28.487	28	1.7	27.394	27	1.5
155	30.555	29.02	5.3	28.506	27.94	2.0	27.414	27.13	1.0
160	30.579	29.25	4.5	28.522	28.1	1.5	27.432	27.05	1.4
165	30.601	29.13	5.0	28.536	28.13	1.4	27.448	27.15	1.1
170	30.620	29.13	5.1	28.549	28.1	1.6	27.462	27.25	0.8
175	30.637	29.15	5.1	28.561	28	2.0	27.475	27.33	0.5
180	30.653	29.27	4.7	28.571	28.23	1.2	27.487	27.2	1.1
185	30.666	29.08	5.5	28.580	28.1	1.7	27.497	27.2	1.1
190	30.678	29.27	4.8	28.589	28.23	1.3	27.506	27.25	0.9

Table 5.1 (continued).

Time	T(129,8) Predicted	T(129,8) Measured	% Error	T(129,5) Predicted	T(129,5) Measured	% Error	T(129,2) Predicted	T(129,2) Measured	% Error
0	25.000	25.27	1.1	25.000	25.27	1.1	25.000	24.98	0.1
5	25.394	25.64	1.0	25.168	25.39	0.9	25.037	25.3	1.0
10	25.819	26.23	1.6	25.427	25.79	1.4	25.143	25.3	0.6
15	26.224	26.91	2.5	25.682	26.1	1.6	25.263	25.61	1.4
20	26.608	27.23	2.3	25.931	26.49	2.1	25.392	25.69	1.2
25	26.973	27.71	2.7	26.173	26.84	2.5	25.529	25.79	1.0
30	27.320	28.05	2.6	26.407	27.17	2.8	25.672	26.17	1.9
35	27.648	28.45	2.8	26.632	27.3	2.4	25.818	26.38	2.1
40	27.959	28.64	2.4	26.849	27.64	2.9	25.965	26.17	0.8
45	28.252	28.94	2.4	27.055	27.79	2.6	26.113	26.66	2.1
50	28.529	29.38	2.9	27.252	27.95	2.5	26.259	26.51	0.9
55	28.790	29.48	2.3	27.439	28	2.0	26.403	26.61	0.8
60	29.034	29.66	2.1	27.615	28.42	2.8	26.544	26.84	1.1
65	29.264	29.79	1.8	27.781	28.33	1.9	26.680	26.89	0.8
70	29.479	29.94	1.5	27.938	28.45	1.8	26.812	26.95	0.5
75	29.680	30.1	1.4	28.084	28.64	1.9	26.938	26.95	0.0
80	29.867	29.99	0.4	28.222	28.79	2.0	27.059	27	0.2
85	30.041	30.45	1.3	28.350	28.84	1.7	27.174	27.2	0.1
90	30.203	30.5	1.0	28.469	28.89	1.5	27.283	27.49	0.8
95	30.353	30.45	0.3	28.579	28.91	1.1	27.386	27.33	0.2
100	30.491	30.56	0.2	28.681	28.96	1.0	27.483	27.56	0.3
105	30.620	30.59	0.1	28.776	29.02	0.8	27.574	27.35	0.8
110	30.738	30.74	0.0	28.864	29.17	1.1	27.660	27.54	0.4
115	30.847	30.64	0.7	28.944	29.17	0.8	27.739	27.49	0.9
120	30.947	30.86	0.3	29.018	29.3	1.0	27.813	27.56	0.9
125	31.039	31.01	0.1	29.086	29.35	0.9	27.882	27.61	1.0
130	31.123	31.01	0.4	29.149	29.3	0.5	27.946	27.71	0.9
135	31.200	30.91	0.9	29.206	29.35	0.5	28.005	27.61	1.4
140	31.270	30.86	1.3	29.259	29.3	0.1	28.059	27.66	1.4
145	31.335	30.99	1.1	29.306	29.38	0.3	28.110	27.59	1.9
150	31.393	31.04	1.1	29.349	29.48	0.4	28.156	27.69	1.7
155	31.447	31.06	1.2	29.389	29.45	0.2	28.198	27.91	1.0
160	31.495	31.23	0.8	29.425	29.51	0.3	28.237	27.79	1.6
165	31.539	31.23	1.0	29.457	29.56	0.3	28.273	27.64	2.3
170	31.580	31.48	0.3	29.487	29.71	0.7	28.306	27.89	1.5
175	31.616	31.42	0.6	29.514	29.76	0.8	28.335	27.89	1.6
180	31.649	31.55	0.3	29.539	29.69	0.5	28.363	27.86	1.8
185	31.679	31.42	0.8	29.561	29.71	0.5	28.387	27.84	2.0
190	31.706	31.23	1.5	29.581	29.76	0.6	28.410	27.89	1.9

Table 5.2: Comparison between Predicted and Measured Temperatures for Small Rashig Ring Run # 7, Temperature in °C and Time in minutes.

Time	T(30,8) Predicted	T(30,8) Measured	% Error	T(30,5) Predicted	T(30,5) Measured	% Error	T(30,2) Predicted	T(30,2) Measured	% Error
0	27.600	27.37	0.8	27.600	27.27	1.2	27.600	27.33	1.0
5	27.991	27.13	3.1	27.680	27.17	1.8	27.610	27.08	1.9
10	28.386	27.15	4.4	27.809	27.05	2.7	27.642	27.2	1.6
15	28.717	27.08	5.7	27.918	27.08	3.0	27.672	27.08	2.1
20	28.988	27.15	6.3	28.006	27.1	3.2	27.699	27	2.5
25	29.209	27.17	7.0	28.077	27.13	3.4	27.723	27.02	2.5
30	29.389	27.33	7.0	28.134	27.17	3.4	27.743	27.23	1.8
35	29.533	27.13	8.1	28.180	27.23	3.4	27.760	27.17	2.1
40	29.649	27.27	8.0	28.216	27.33	3.1	27.775	27.23	2.0
45	29.742	27.42	7.8	28.246	27.33	3.2	27.788	27.27	1.9
50	29.816	27.49	7.8	28.269	27.3	3.4	27.798	27.25	2.0
55	29.876	27.51	7.9	28.288	27.37	3.2	27.807	27.37	1.6
60	29.923	27.44	8.3	28.303	27.44	3.0	27.814	27.3	1.8
65	29.960	27.56	8.0	28.315	27.37	3.3	27.821	27.51	1.1
70	29.990	27.66	7.8	28.325	27.44	3.1	27.826	27.2	2.2
75	30.014	27.71	7.7	28.332	27.66	2.4	27.830	27.46	1.3
80	30.033	27.66	7.9	28.339	27.61	2.6	27.834	27.46	1.3
85	30.048	27.59	8.2	28.344	27.64	2.5	27.837	27.35	1.7
90	30.060	27.74	7.7	28.348	27.69	2.3	27.839	27.59	0.9
95	30.069	27.74	7.7	28.351	27.59	2.7	27.841	27.49	1.3
100	30.077	27.79	7.6	28.353	27.84	1.8	27.843	27.51	1.2
105	30.083	27.74	7.8	28.355	27.74	2.2	27.845	27.54	1.1
110	30.088	27.81	7.6	28.357	27.81	1.9	27.846	27.66	0.7
115	30.092	27.84	7.5	28.358	27.79	2.0	27.847	27.64	0.7
120	30.095	28	7.0	28.359	27.86	1.8	27.847	27.71	0.5
125	30.097	27.94	7.2	28.360	27.79	2.0	27.848	27.59	0.9
130	30.099	27.98	7.0	28.361	27.94	1.5	27.849	27.64	0.7
135	30.101	27.98	7.0	28.362	27.84	1.8	27.849	27.74	0.4
140	30.102	27.89	7.3	28.362	27.98	1.3	27.849	27.74	0.4
145	30.103	27.91	7.3	28.362	27.86	1.8	27.850	27.66	0.7
150	30.104	28.02	6.9	28.363	27.84	1.8	27.850	27.74	0.4
155	30.104	28.05	6.8	28.363	27.91	1.6	27.850	27.71	0.5
160	30.105	28.1	6.7	28.363	28	1.3	27.850	27.76	0.3
165	30.105	28	7.0	28.363	27.95	1.5	27.851	27.81	0.1
170	30.105	28.05	6.8	28.363	28	1.3	27.851	27.76	0.3
175	30.106	28.13	6.6	28.363	27.98	1.4	27.851	27.79	0.2
180	30.106	28.17	6.4	28.364	27.98	1.4	27.851	27.74	0.4
185	30.106	28.02	6.9	28.364	28.02	1.2	27.851	27.89	0.1
190	30.106	28.17	6.4	28.364	27.98	1.4	27.851	27.84	0.0

Table 5.2 (continued).

Time	T(63,8) Predicted	T(63,8) Measured	% Error	T(63,5) Predicted	T(63,5) Measured	% Error	T(63,2) Predicted	T(63,2) Measured	% Error
0	27.600	27.37	0.8	27.600	27.37	0.8	27.600	27.51	0.3
5	28.031	27.33	2.5	27.713	27.37	1.2	27.624	27.37	0.9
10	28.519	27.64	3.1	27.924	27.49	1.6	27.687	27.4	1.0
15	28.959	27.74	4.2	28.122	27.49	2.2	27.756	27.49	1.0
20	29.346	27.89	5.0	28.294	27.64	2.3	27.820	27.44	1.4
25	29.682	28.08	5.4	28.440	27.84	2.1	27.880	27.56	1.1
30	29.973	28.33	5.5	28.564	27.95	2.2	27.933	27.76	0.6
35	30.223	28.51	5.7	28.669	28.15	1.8	27.981	27.71	1.0
40	30.436	28.86	5.2	28.758	28.25	1.8	28.024	27.71	1.1
45	30.617	29.13	4.9	28.832	28.38	1.6	28.062	27.98	0.3
50	30.770	28.99	5.8	28.894	28.4	1.7	28.094	27.94	0.5
55	30.898	29.27	5.3	28.946	28.51	1.5	28.123	27.91	0.8
60	31.005	29.23	5.7	28.989	28.59	1.4	28.148	28.08	0.2
65	31.095	29.42	5.4	29.025	28.76	0.9	28.169	28.33	0.6
70	31.170	29.5	5.4	29.055	28.86	0.7	28.187	28.3	0.4
75	31.231	29.54	5.4	29.079	28.86	0.8	28.202	28.35	0.5
80	31.283	29.61	5.3	29.099	29	0.3	28.216	28.45	0.8
85	31.325	29.74	5.1	29.116	29.15	0.1	28.227	28.45	0.8
90	31.360	29.89	4.7	29.130	29.15	0.1	28.237	28.49	0.9
95	31.388	29.79	5.1	29.141	29.08	0.2	28.245	28.59	1.2
100	31.412	29.86	4.9	29.150	29.23	0.3	28.251	28.51	0.9
105	31.431	29.94	4.7	29.158	29.17	0.0	28.257	28.69	1.5
110	31.447	30.01	4.6	29.164	29.25	0.3	28.262	28.74	1.7
115	31.459	30.08	4.4	29.169	29.27	0.3	28.266	28.66	1.4
120	31.470	29.96	4.8	29.174	29.4	0.8	28.269	28.66	1.4
125	31.479	30.04	4.6	29.177	29.35	0.6	28.272	28.79	1.8
130	31.486	30.23	4.0	29.180	29.42	0.8	28.275	28.71	1.5
135	31.491	30.13	4.3	29.182	29.5	1.1	28.277	28.79	1.8
140	31.496	30.13	4.3	29.184	29.42	0.8	28.278	28.84	2.0
145	31.500	30.25	4.0	29.186	29.5	1.1	28.280	28.86	2.1
150	31.503	30.17	4.2	29.187	29.42	0.8	28.281	28.84	2.0
155	31.505	30.25	4.0	29.188	29.56	1.3	28.282	29	2.5
160	31.507	30.4	3.5	29.189	29.64	1.5	28.282	29.05	2.7
165	31.509	30.35	3.7	29.190	29.5	1.1	28.283	29	2.5
170	31.510	30.4	3.5	29.190	29.54	1.2	28.284	29.08	2.8
175	31.512	30.52	3.1	29.191	29.61	1.4	28.284	29	2.5
180	31.512	30.33	3.8	29.191	29.61	1.4	28.284	28.91	2.2
185	31.513	30.59	2.9	29.191	29.59	1.4	28.285	29.02	2.6
190	31.514	30.56	3.0	29.192	29.56	1.3	28.285	29	2.5

Table 5.2 (continued).

Time	T(96,8) Predicted	T(96,8) Measured	% Error	T(96,5) Predicted	T(96,5) Measured	% Error	T(96,2) Predicted	T(96,2) Measured	% Error
0	27.600	27.76	0.6	27.600	27.61	0.0	27.600	27.95	1.3
5	28.038	27.68	1.3	27.720	27.51	0.8	27.628	27.81	0.7
10	28.572	27.83	2.6	27.991	27.81	0.6	27.720	27.79	0.3
15	29.096	28.01	3.7	28.295	27.94	1.3	27.847	27.94	0.3
20	29.590	28.24	4.6	28.590	28.15	1.5	27.985	27.98	0.0
25	30.049	28.42	5.4	28.865	28.23	2.2	28.125	27.95	0.6
30	30.473	28.60	6.1	29.120	28.56	1.9	28.264	28.05	0.8
35	30.863	28.93	6.3	29.354	28.76	2.0	28.400	28.05	1.2
40	31.221	29.26	6.3	29.568	29	1.9	28.531	28.25	1.0
45	31.547	29.62	6.1	29.762	29.23	1.8	28.655	28.49	0.6
50	31.842	29.66	6.9	29.937	29.3	2.1	28.772	28.48	1.0
55	32.110	29.81	7.2	30.095	29.48	2.0	28.881	28.64	0.8
60	32.351	30.02	7.2	30.236	29.74	1.6	28.982	28.86	0.4
65	32.566	30.24	7.1	30.362	29.91	1.5	29.075	28.74	1.2
70	32.759	30.31	7.5	30.473	29.96	1.7	29.160	28.96	0.7
75	32.930	30.51	7.3	30.572	30.01	1.8	29.237	29.1	0.5
80	33.082	30.73	7.1	30.659	30.27	1.3	29.306	29.15	0.5
85	33.216	30.78	7.3	30.735	30.3	1.4	29.368	29.2	0.6
90	33.334	30.95	7.2	30.801	30.35	1.5	29.424	29.23	0.7
95	33.438	31.02	7.2	30.859	30.5	1.2	29.473	29.42	0.2
100	33.528	31.18	7.0	30.910	30.42	1.6	29.517	29.45	0.2
105	33.607	31.15	7.3	30.954	30.64	1.0	29.556	29.4	0.5
110	33.676	31.31	7.0	30.992	30.71	0.9	29.590	29.45	0.5
115	33.736	31.49	6.7	31.024	30.69	1.1	29.620	29.64	0.1
120	33.787	31.41	7.0	31.053	30.91	0.5	29.646	29.61	0.1
125	33.832	31.47	7.0	31.077	30.91	0.5	29.669	29.74	0.2
130	33.870	31.57	6.8	31.098	30.99	0.3	29.689	29.81	0.4
135	33.903	31.68	6.6	31.115	31.06	0.2	29.706	29.84	0.5
140	33.931	31.65	6.7	31.131	30.94	0.6	29.721	29.81	0.3
145	33.955	31.75	6.5	31.144	31.06	0.3	29.734	29.89	0.5
150	33.976	31.78	6.5	31.155	30.99	0.5	29.745	29.74	0.0
155	33.993	31.83	6.4	31.164	31.33	0.5	29.754	30.04	1.0
160	34.008	32.03	5.8	31.172	31.01	0.5	29.763	30.01	0.8
165	34.021	31.93	6.1	31.179	31.33	0.5	29.770	29.96	0.6
170	34.032	31.98	6.0	31.184	31.3	0.4	29.776	30.13	1.2
175	34.041	32.11	5.7	31.189	31.27	0.3	29.781	30.15	1.2
180	34.048	31.94	6.2	31.193	31.38	0.6	29.785	30.17	1.3
185	34.055	32.17	5.5	31.197	31.45	0.8	29.789	29.99	0.7
190	34.060	32.23	5.4	31.200	31.48	0.9	29.792	30.17	1.3

Table 5.2 (continued).

Time	T(129,8) Predicted	T(129,8) Measured	% Error	T(129,5) Predicted	T(129,5) Measured	% Error	T(129,2) Predicted	T(129,2) Measured	% Error
0	27.600	27.95	1.3	27.600	28	1.4	27.600	27.95	1.3
5	27.999	28.02	0.1	27.663	27.91	0.9	27.588	27.86	1.0
10	28.519	28.02	1.8	27.921	28.25	1.2	27.668	28.02	1.3
15	29.045	28.27	2.7	28.235	28.42	0.7	27.796	28.13	1.2
20	29.552	28.59	3.3	28.557	28.59	0.1	27.947	28.08	0.5
25	30.036	28.76	4.2	28.871	28.86	0.0	28.109	28.27	0.6
30	30.494	28.86	5.4	29.173	28.96	0.7	28.279	28.51	0.8
35	30.926	29.35	5.1	29.461	29.3	0.5	28.453	28.59	0.5
40	31.332	29.66	5.3	29.735	29.66	0.3	28.627	28.81	0.6
45	31.714	30.1	5.1	29.992	29.81	0.6	28.801	29	0.7
50	32.070	30.33	5.4	30.234	30.17	0.2	28.970	29.17	0.7
55	32.402	30.35	6.3	30.459	30.4	0.2	29.135	29.35	0.7
60	32.710	30.81	5.8	30.669	30.81	0.5	29.294	29.81	1.8
65	32.995	31.06	5.9	30.862	30.89	0.1	29.445	29.99	1.9
70	33.257	31.12	6.4	31.040	31.04	0.0	29.587	30.23	2.2
75	33.498	31.48	6.0	31.202	31.33	0.4	29.722	30.2	1.6
80	33.719	31.84	5.6	31.351	31.48	0.4	29.847	30.4	1.9
85	33.920	31.81	6.2	31.486	31.71	0.7	29.964	30.59	2.1
90	34.102	32.01	6.1	31.608	31.96	1.1	30.072	30.64	1.9
95	34.268	32.25	5.9	31.718	32.11	1.2	30.171	30.84	2.2
100	34.417	32.5	5.6	31.817	32.22	1.3	30.261	31.15	2.9
105	34.552	32.35	6.4	31.906	32.25	1.1	30.344	31.27	3.1
110	34.673	32.6	6.0	31.985	32.25	0.8	30.419	31.33	3.0
115	34.781	32.89	5.4	32.056	32.33	0.9	30.487	31.3	2.7
120	34.878	32.86	5.8	32.119	32.55	1.3	30.548	31.42	2.9
125	34.964	32.89	5.9	32.174	32.6	1.3	30.603	31.58	3.2
130	35.040	32.91	6.1	32.223	32.86	2.0	30.652	31.52	2.8
135	35.108	33.22	5.4	32.267	32.89	1.9	30.696	31.69	3.2
140	35.168	33.17	5.7	32.305	32.81	1.6	30.735	31.89	3.8
145	35.220	33.25	5.6	32.338	33.06	2.2	30.769	31.91	3.7
150	35.267	33.38	5.3	32.368	33.01	2.0	30.800	31.81	3.3
155	35.307	33.4	5.4	32.393	33.14	2.3	30.827	32.06	4.0
160	35.343	33.65	4.8	32.416	33.17	2.3	30.851	32.09	4.0
165	35.374	33.5	5.3	32.435	33.22	2.4	30.872	32.25	4.5
170	35.401	33.55	5.2	32.452	33.3	2.6	30.890	32.11	3.9
175	35.425	33.69	4.9	32.467	33.42	2.9	30.906	32.25	4.3
180	35.445	33.55	5.3	32.479	33.33	2.6	30.921	32.3	4.5
185	35.463	33.74	4.9	32.490	33.28	2.4	30.933	32.42	4.8
190	35.479	33.89	4.5	32.500	33.42	2.8	30.943	32.5	5.0

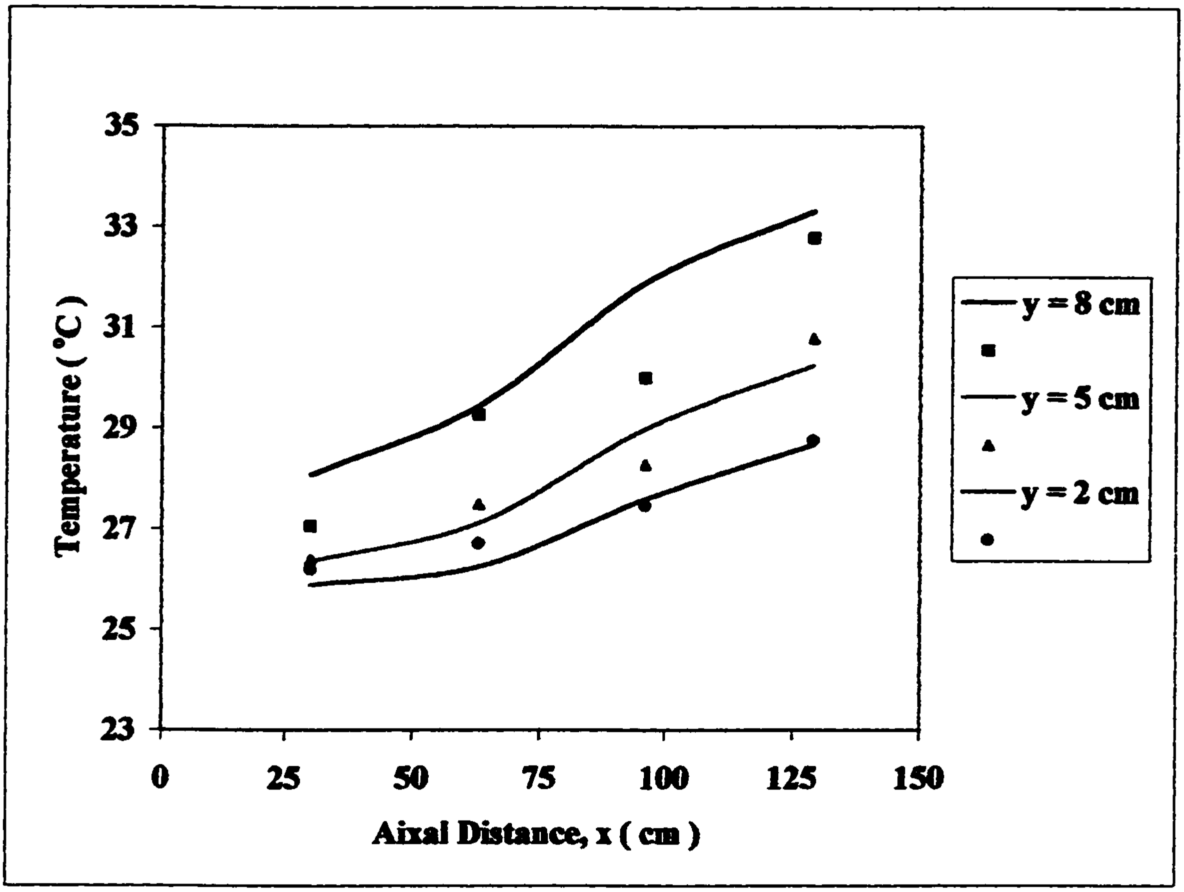


Figure 5.56: Measured and Predicted Axial Airflow Temperature for Small Sphere, $d_p = 2.9$ cm, Run # 2, Re = 756, $Q_w = 243.4\ W/m^2$.

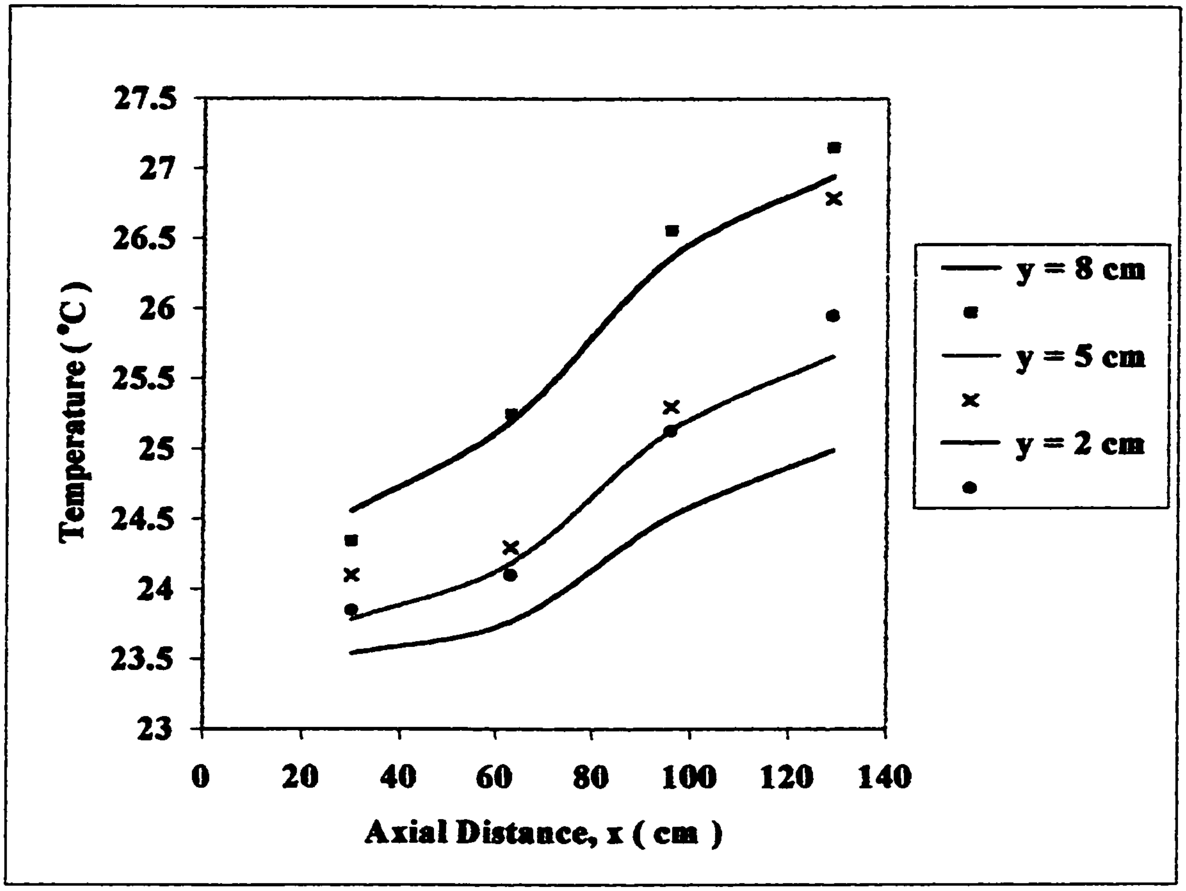


Figure 5.57: Measured and Predicted Axial Airflow Temperature for Medium Sphere, d_p = 3.87 cm, Run # 7, Re = 672.6, Q_w = 79.4 W/m^2.

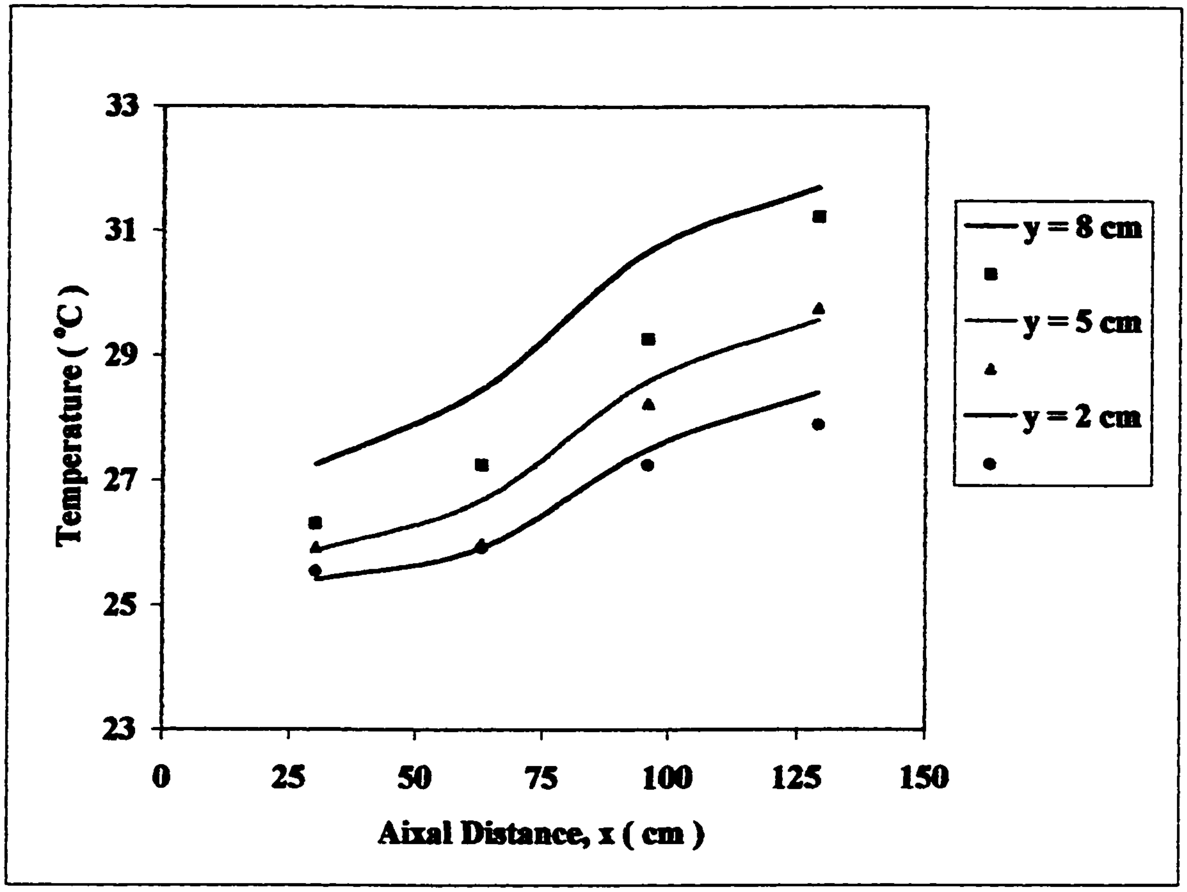


Figure 5.58: Measured and Predicted Axial Airflow Temperature for Large Sphere, $d_p = 5.25$ cm, Run # 2, Re = 1268.1, $Q_w = 243.4$ W/m^2.

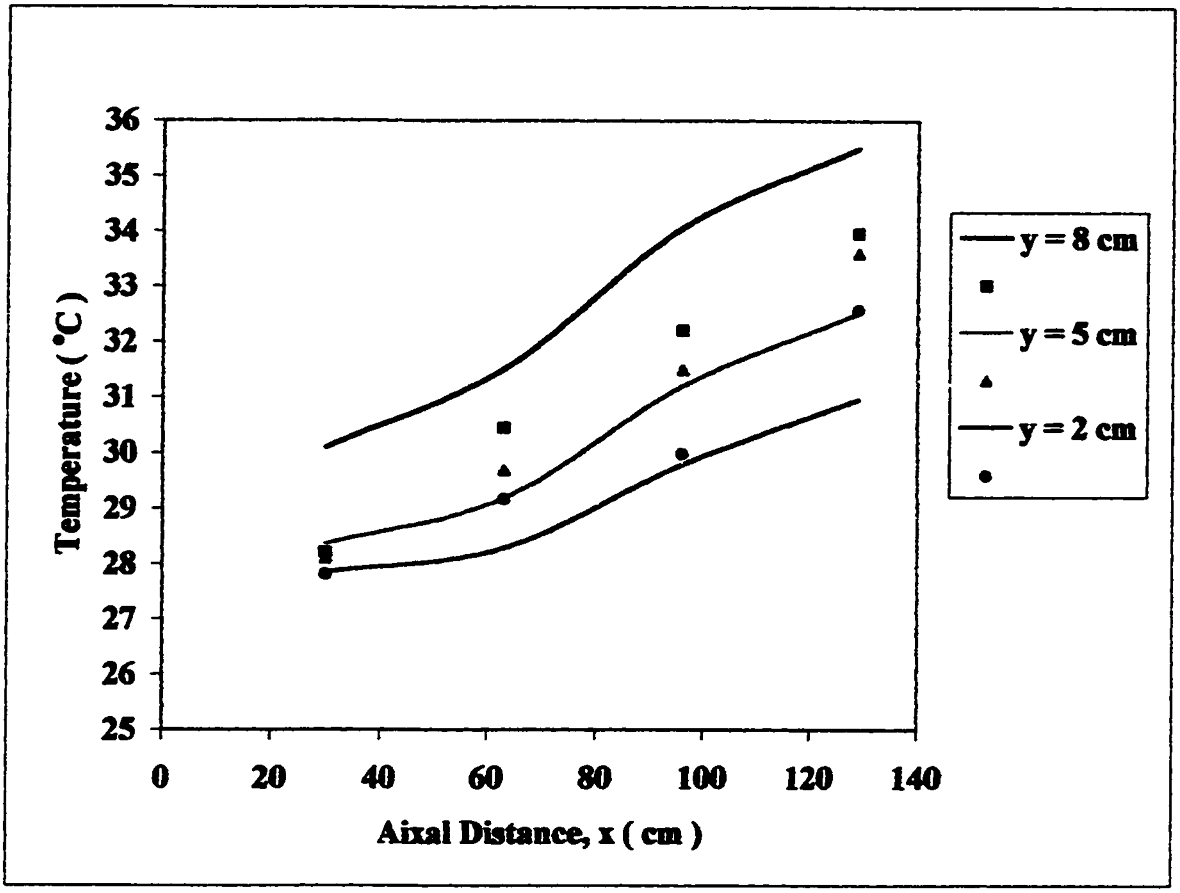


Figure 5.59: Measured and Predicted Axial Airflow Temperature for Small Rashig Ring, d_p = 3.27 cm, Run # 7, Re = 606.8, Q_w = 179.2 W/m^2.

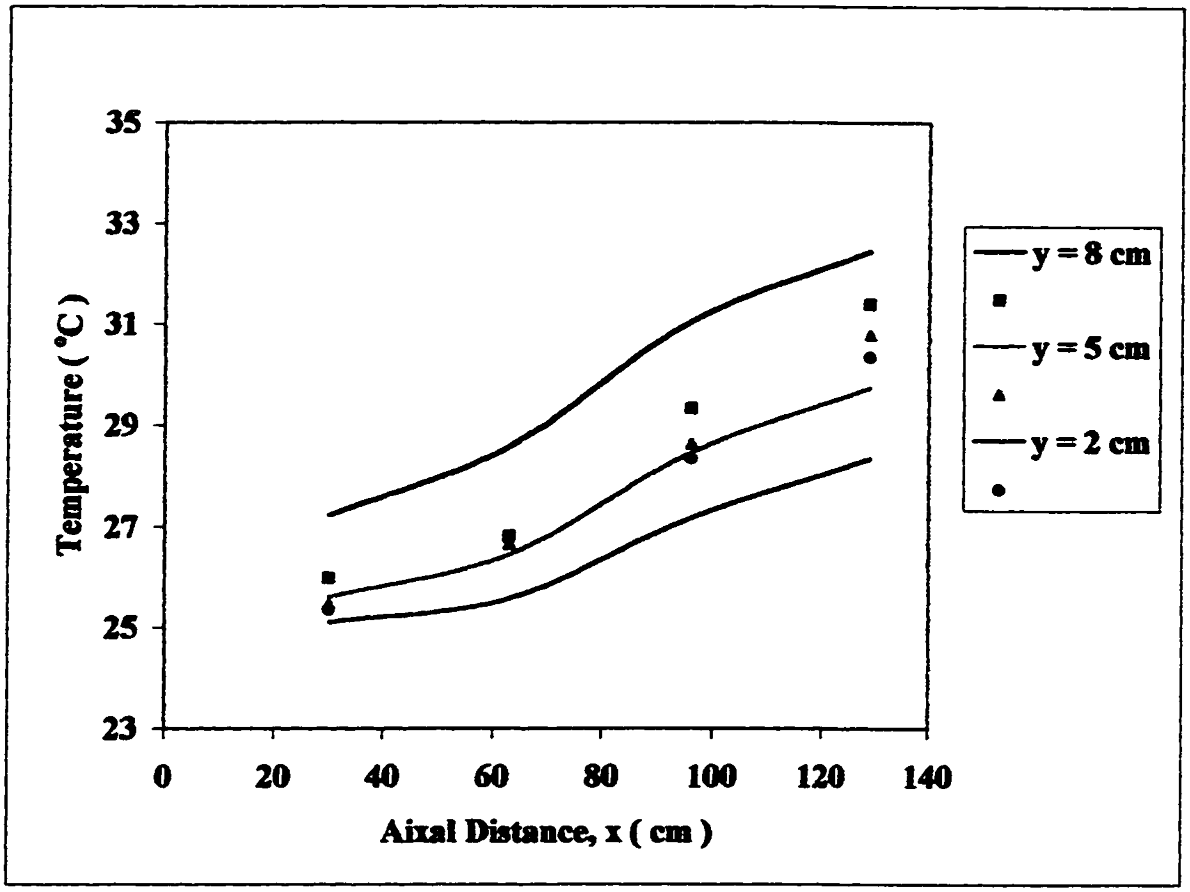


Figure 5.60: Measured and Predicted Axial Airflow Temperature for Large Rashig Ring, d_p = 3.87 cm, Run # 7, Re = 672.6, Q_w = 179.2 W/m^2.

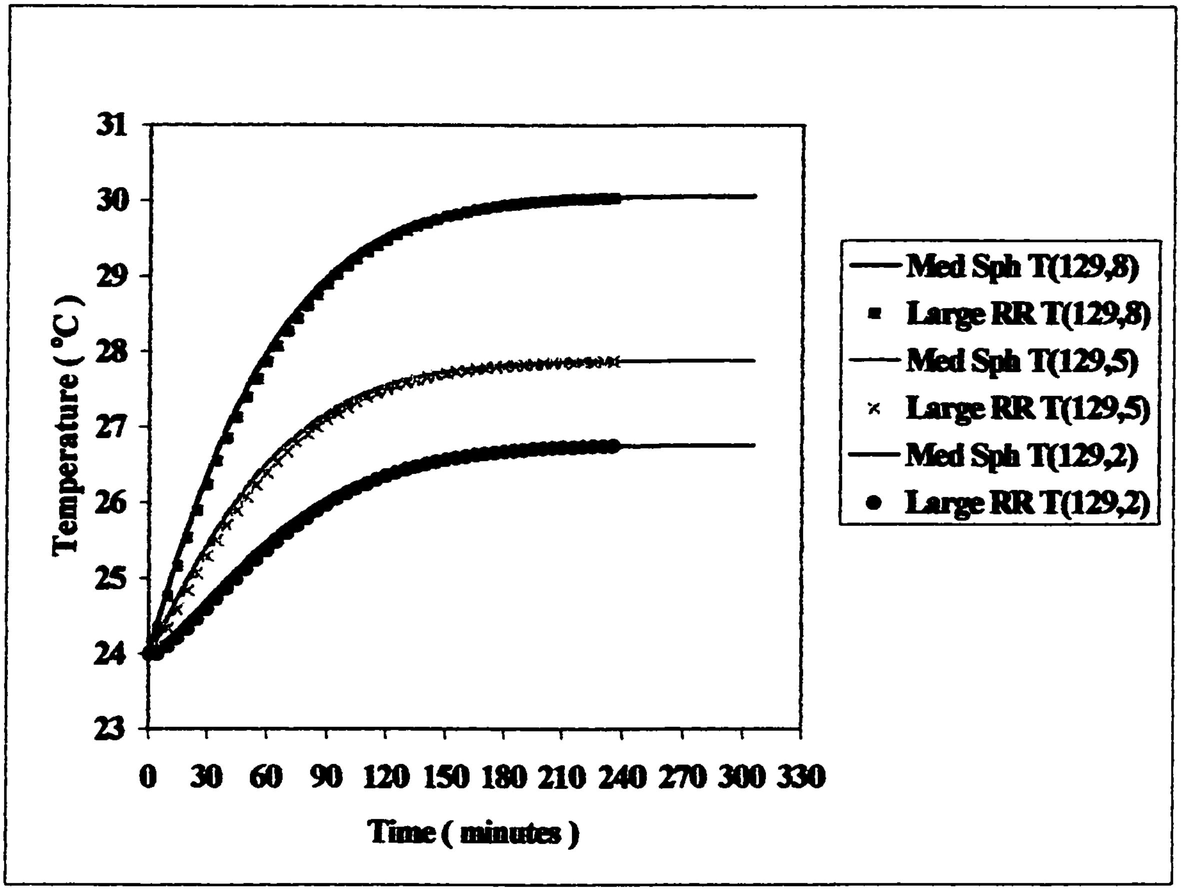


Figure 5.61: Effect of Shape of Packing on Steady State Time, Predicted Data for Medium Sphere and Large Rashig Ring, Re = 1065.9 Q_w = 179.2 W/m^2.

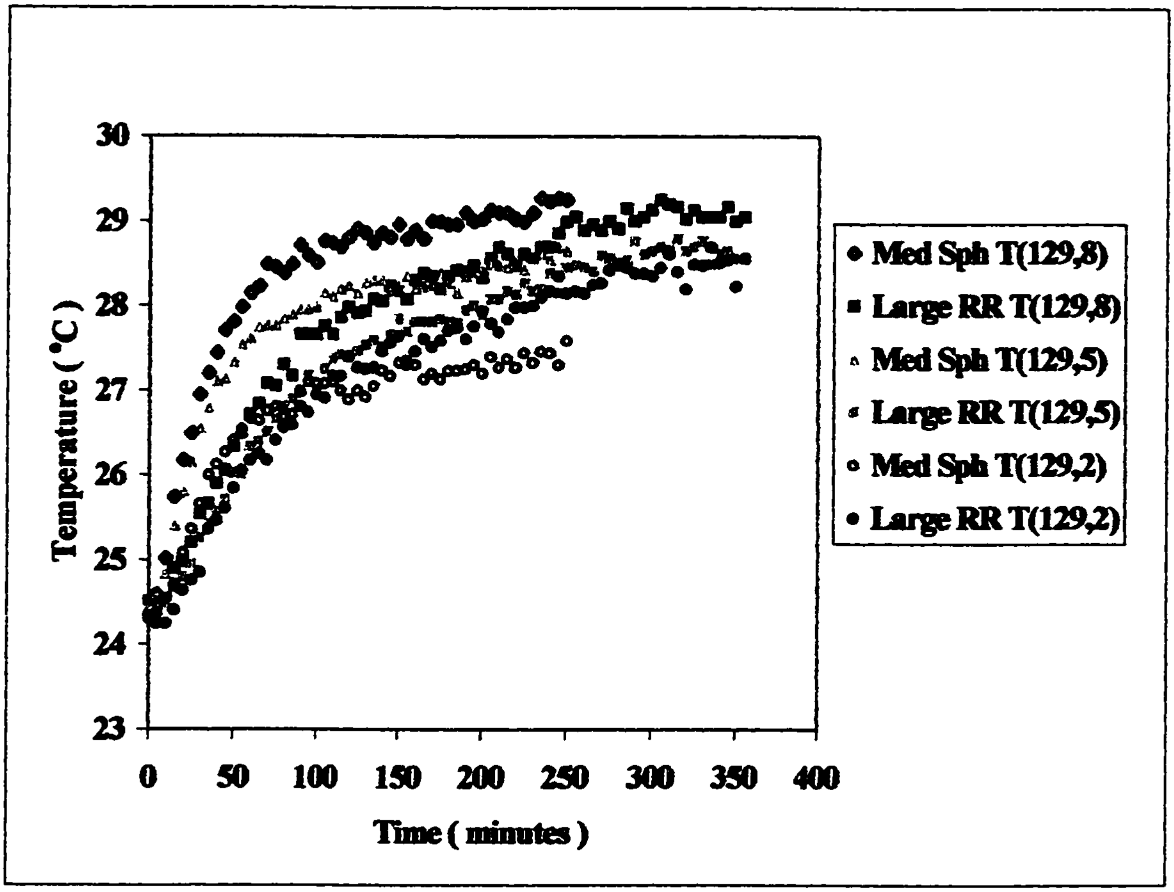


Figure 5.62: Effect of Shape of Packing on Steady State Time, Measured Data for Medium Sphere and Large Rashig Ring, Re = 1065.9 $Q_w = 179.2\ W/m^2$.

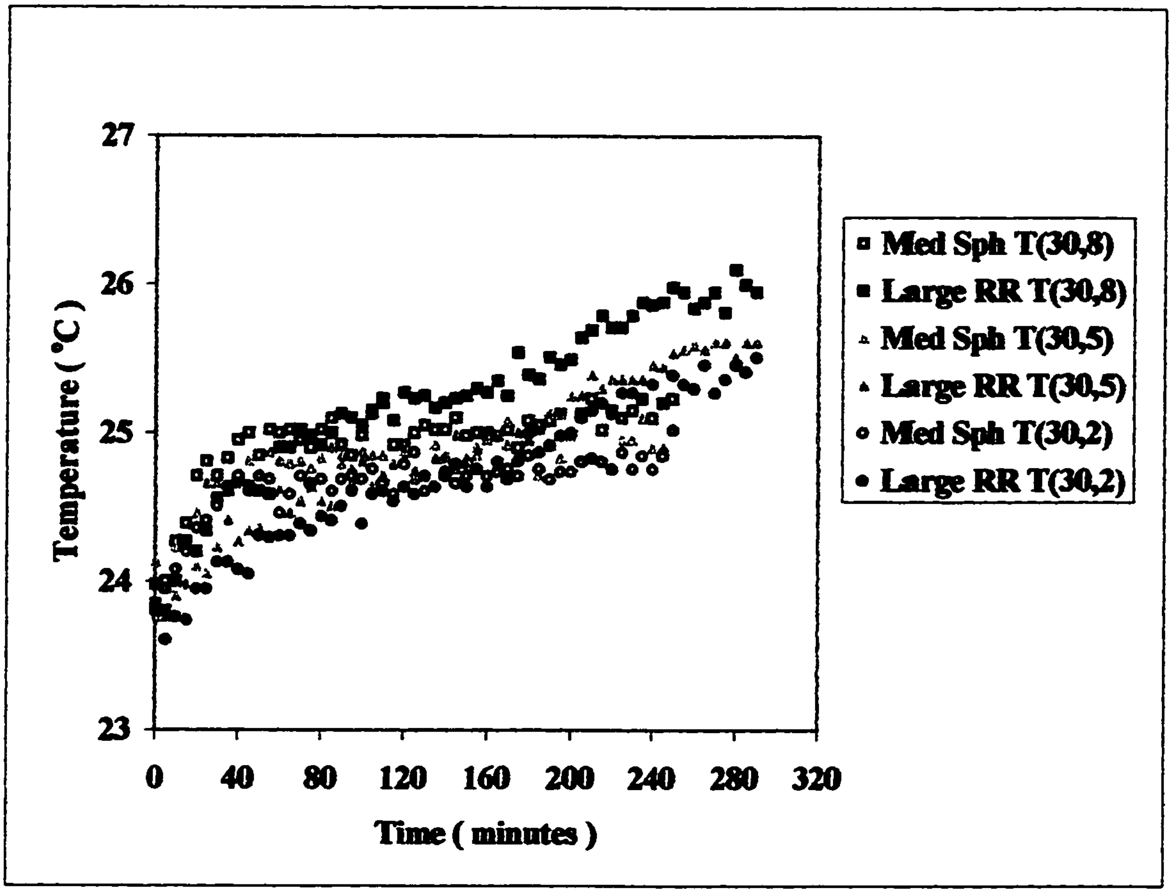


Figure 5.63: Effect of Shape of Packing on Steady State Time, Measured Data for Medium Sphere and Large Rashig Ring, Re = 1065.9 $Q_w = 179.2$ W/m^2.

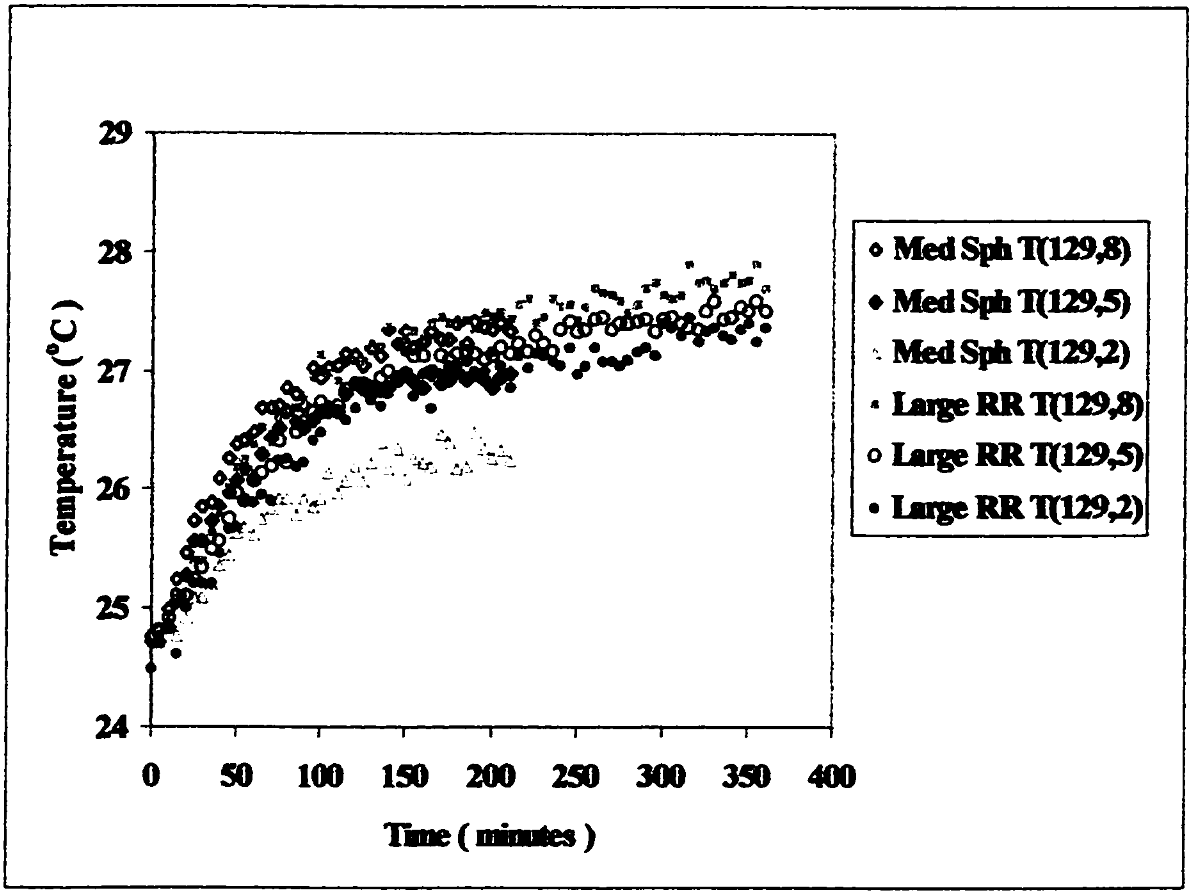


Figure 5.64: Effect of Shape of Packing on Steady State Time, Measured Data for Medium Sphere and Large Rashig Ring, Re = 880.6, $Q_w = 79.4\ W/m^2$.

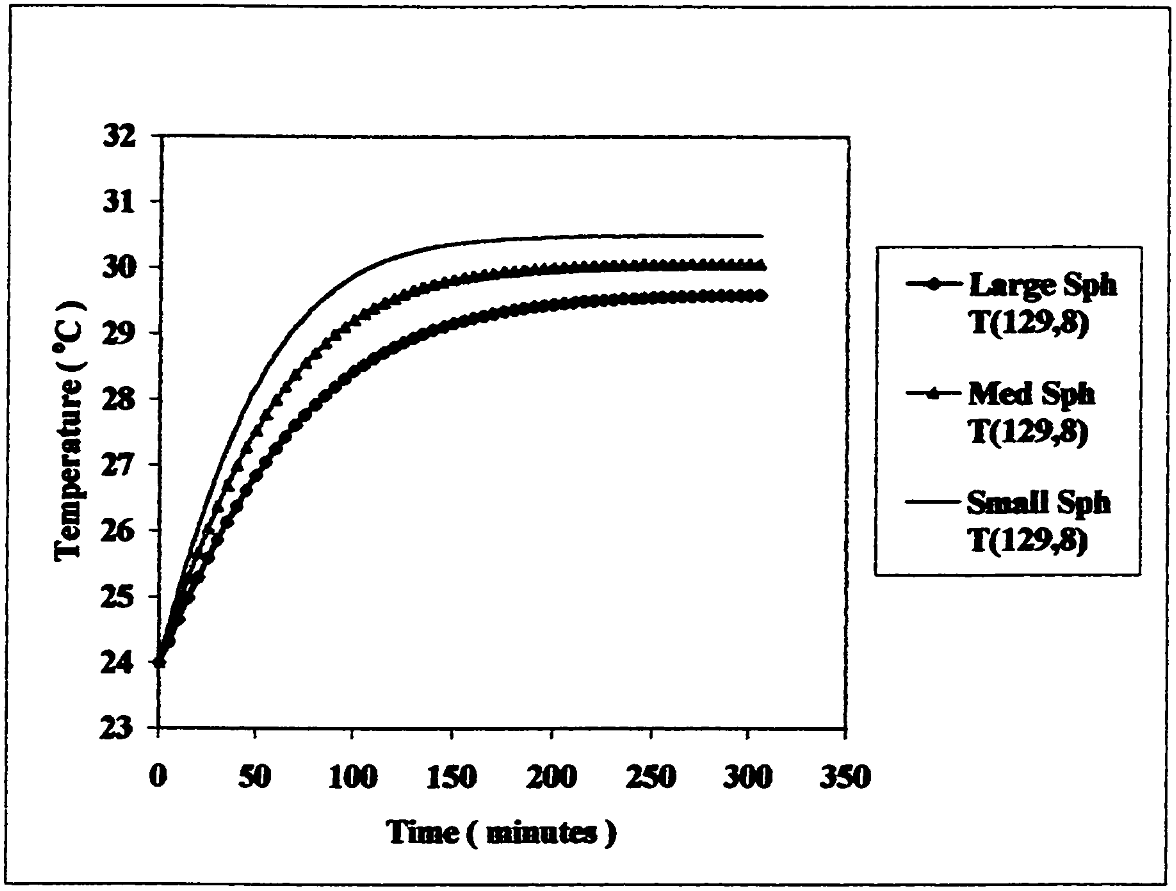


Figure 5.65: Effect of Size of Packing on Predicted Steady State Time, Spherical Packing, Q_w = 179.2 W/m^2, Superficial Velocity = 0.432 m/sec.

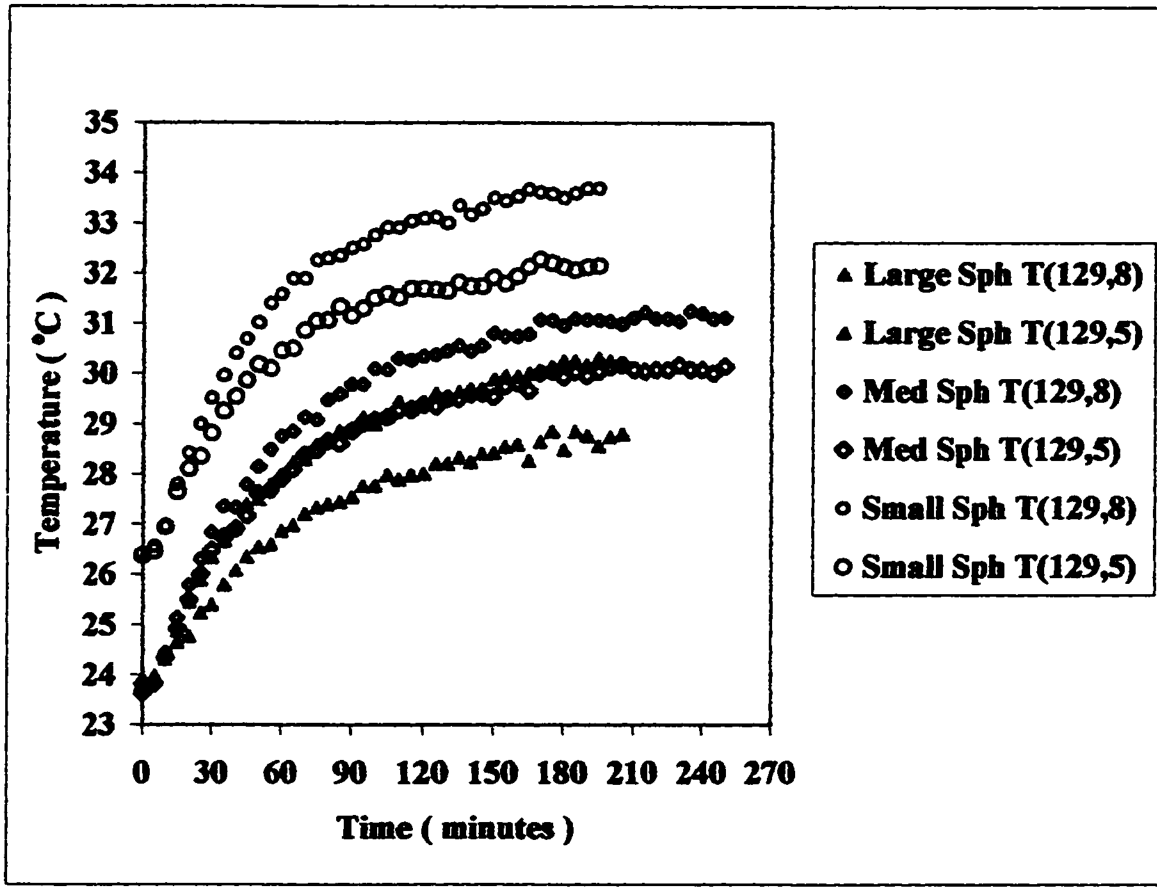


Figure 5.66: Effect of Size of Packing on Measured Steady State Time, Spherical Packing. Small Sphere Run 7, Medium Sphere Run 3 and Large Sphere Run 7.

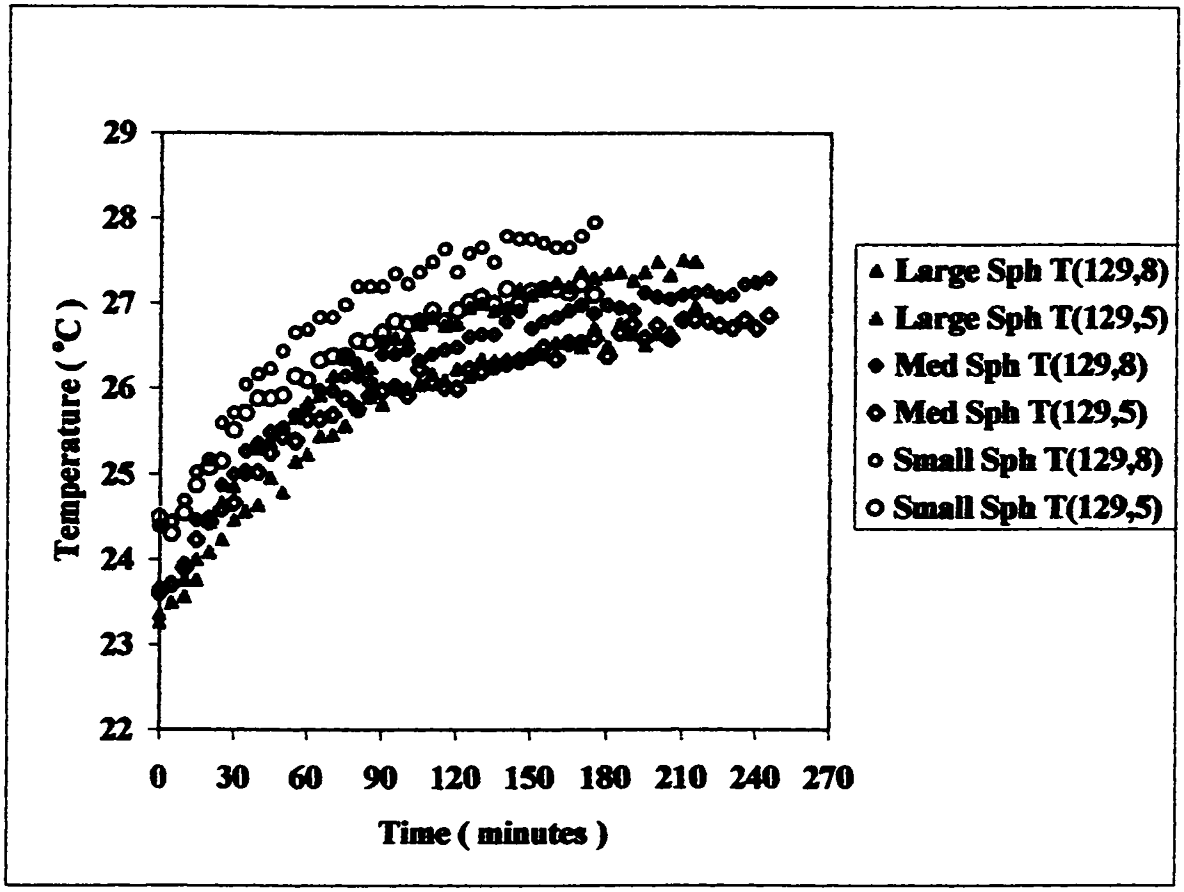


Figure 5.67: Effect of Size of Packing on Measured Steady State Time, Spherical Packing. Small Sphere Run 11, Medium Sphere Run 7 and Large Sphere Run 11.

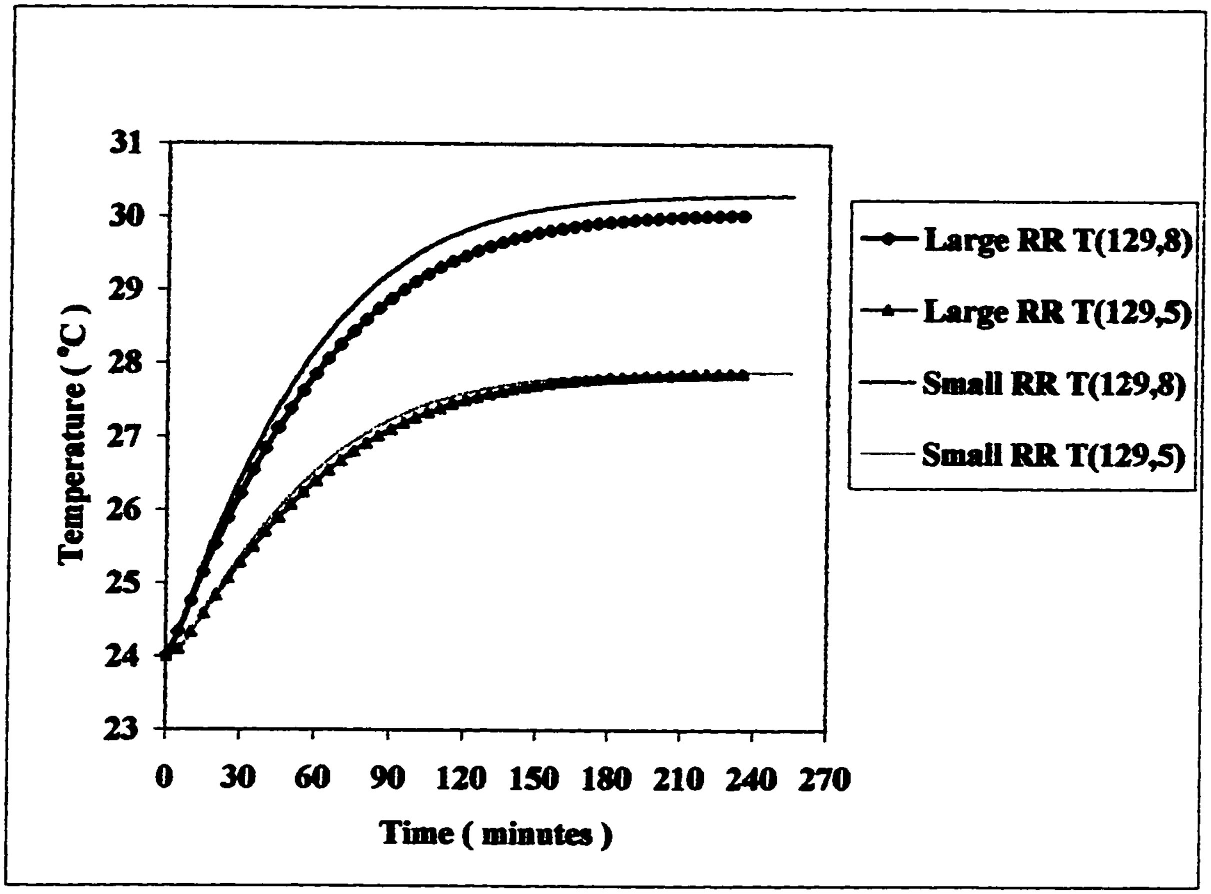


Figure 5.68: Effect of Size of Packing on Predicted Steady State Time. Large Rashig Ring Versus Small Rashig Ring, Q_w = 179.2 W/m^2, Superficial Velocity = 0.432 m/sec.

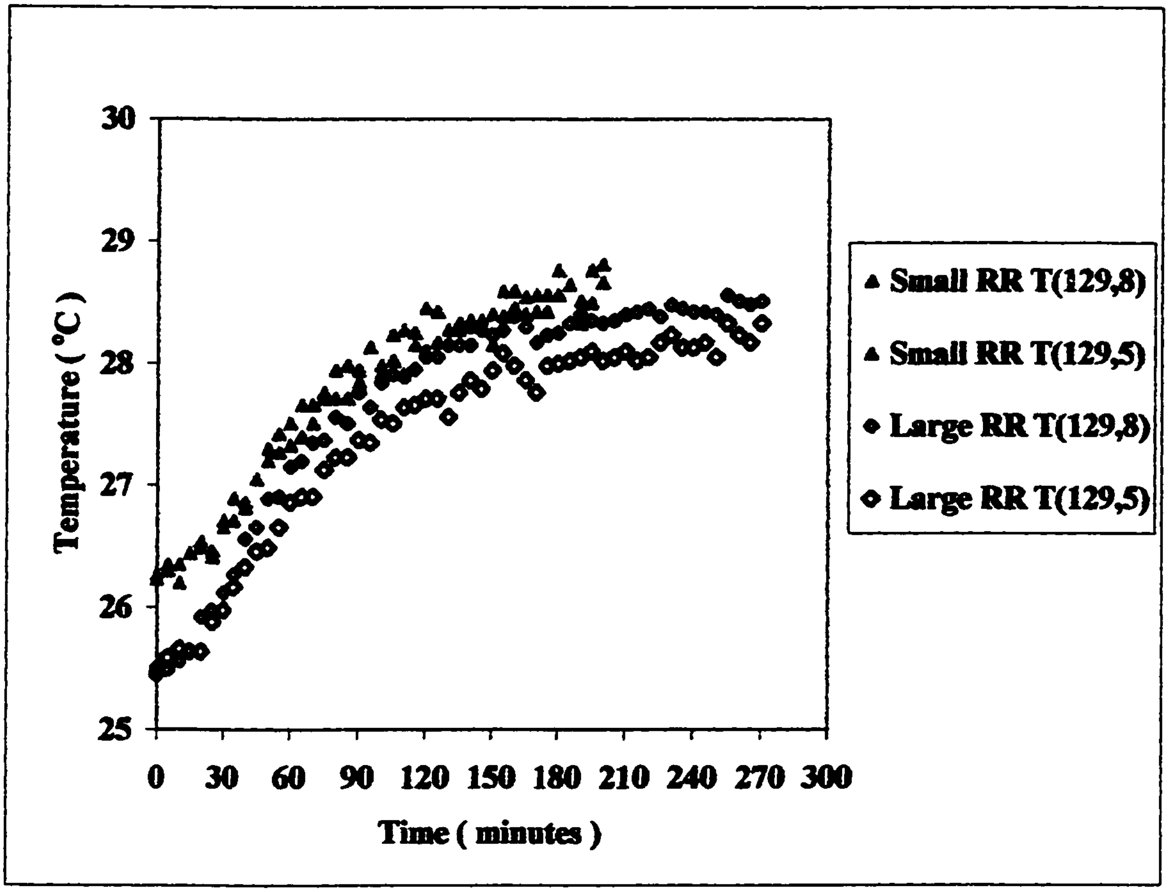


Figure 5.69: Effect of Size of Packing on Measured Steady State Time. Small Rashig Ring Run 10 Versus Large Rashig Ring Run 11.

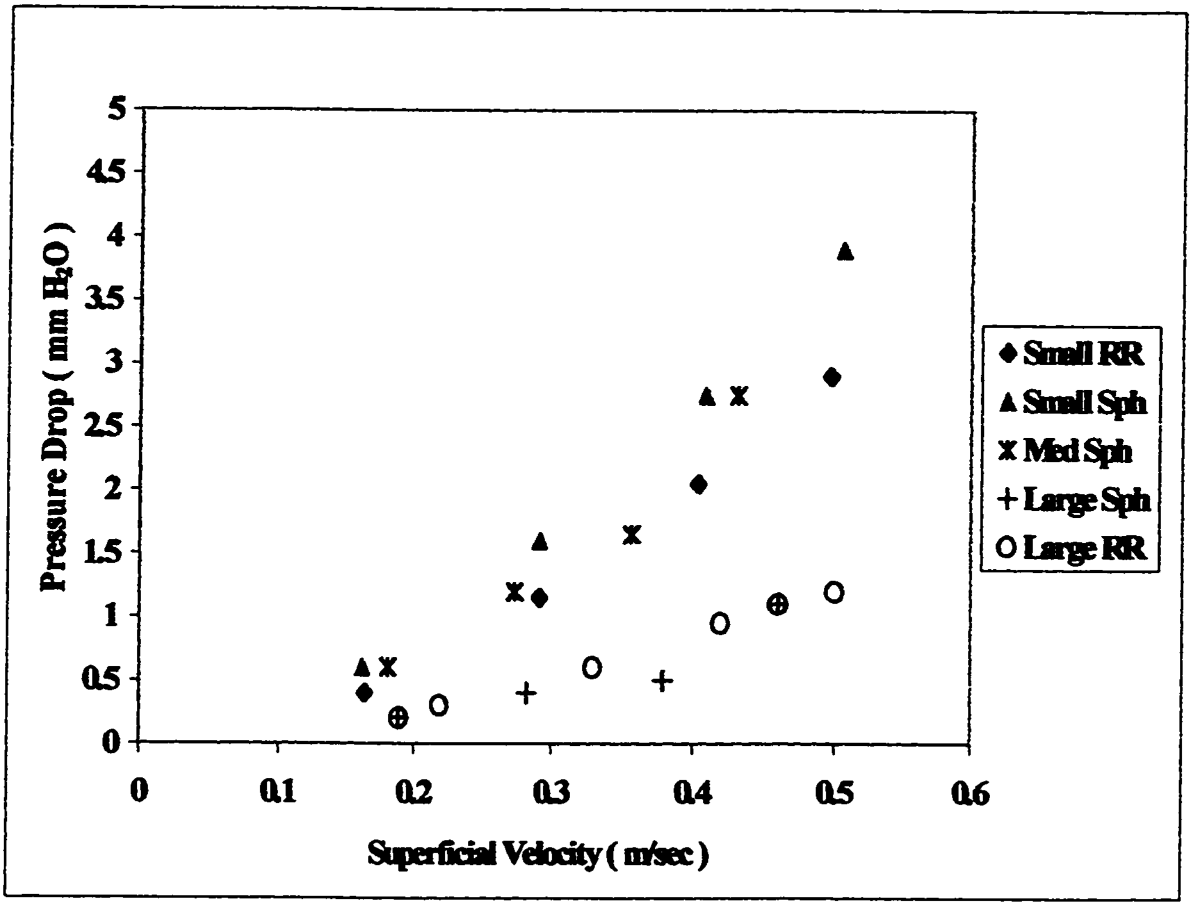


Figure 5.70: Measured Pressure Drop versus Air Superficial Velocity for Different Packing.

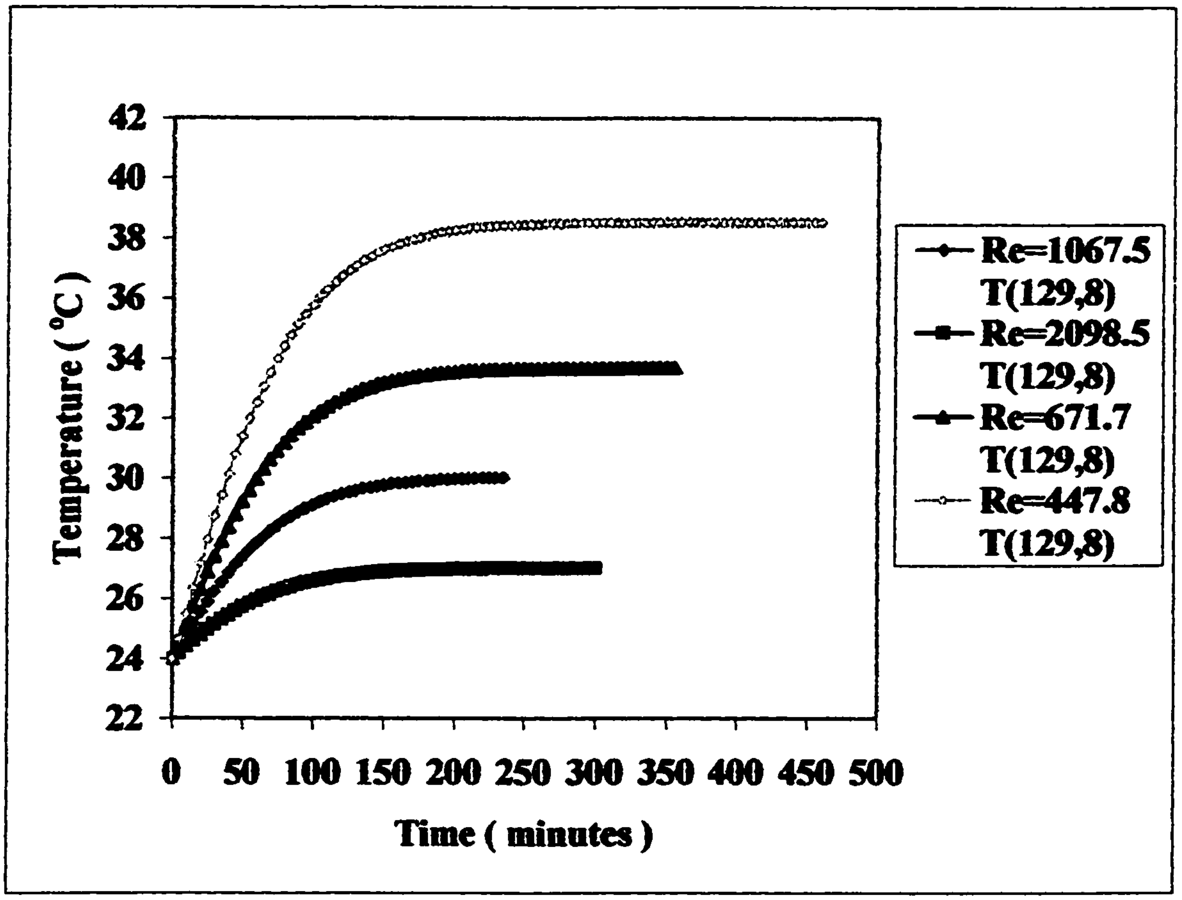


Figure 5.71: Effect of Reynolds Number on Predicted Steady State Time For Large Rashig Ring at x = 129 cm & y = 8 cm, Q_w = 179.2 W/m^2, Re = 2098.5, 1067.5, 671.7 & 447.8.

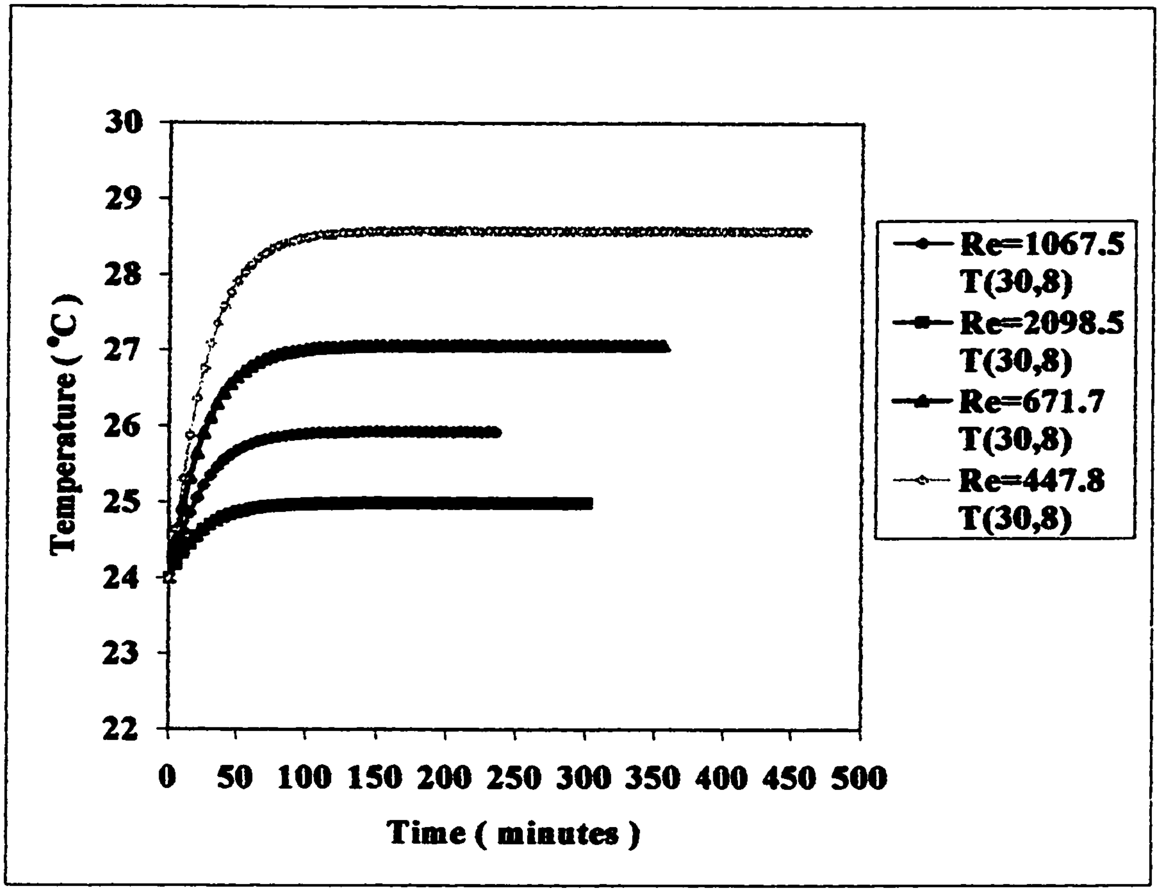


Figure 5.72: Effect of Reynolds Number on Predicted Steady State Time For Large Rashig Ring at x = 30 cm & y = 8 cm, Q_w = 179.2 W/m^2, Re = 2098.5, 1067.5, 671.7 & 447.8.

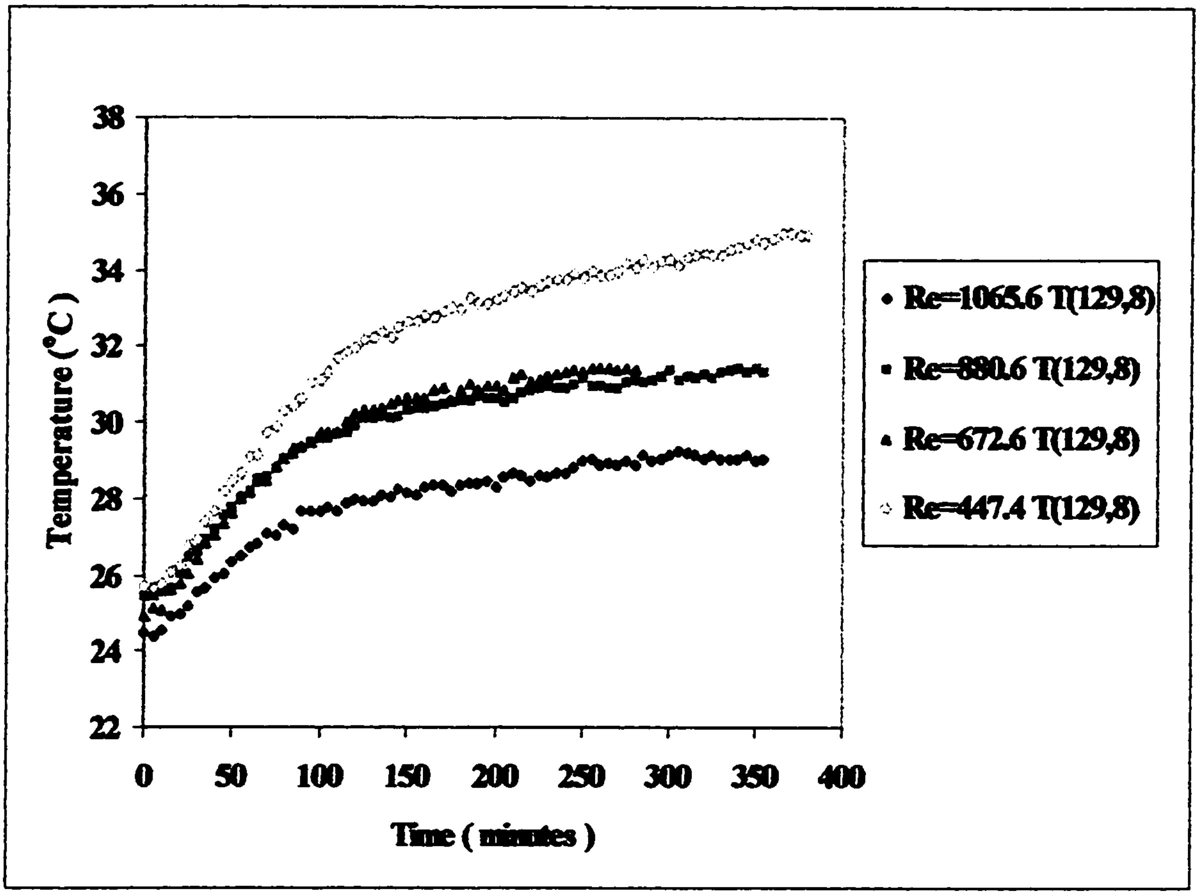


Figure 5.73: Effect of Reynolds Number on Measured Steady State Time For Large Rashig Ring at x = 129 cm & y = 8 cm, Q_w = 179.2 W/m^2, Re = 1065.9, 880.6 & 447.4.

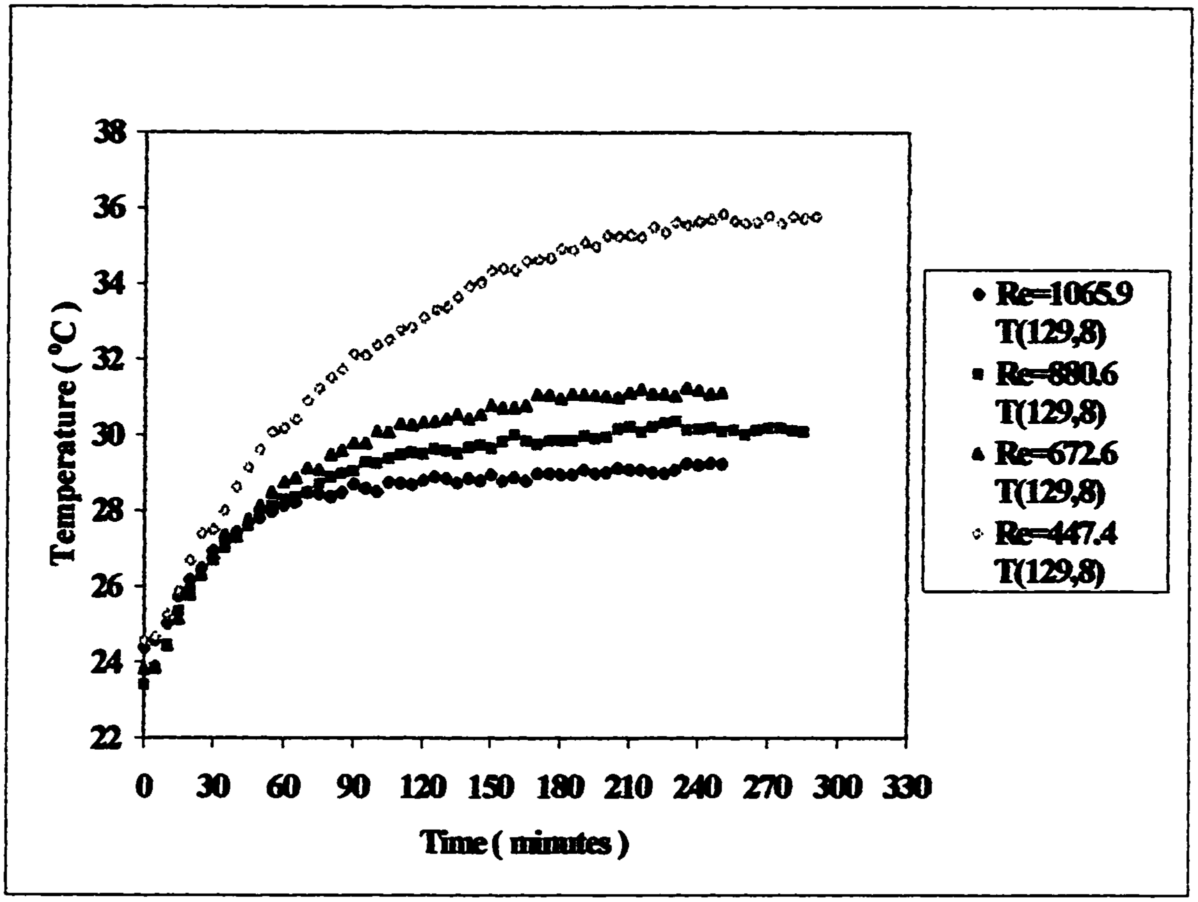


Figure 5.74: Effect of Reynolds Number on Measured Steady State Time For Medium Sphere at x = 129 cm & y = 8 cm, Q_w = 179.2 W/m^2, Re = 1065.9, 880.6 & 447.4.

Table 5.3: Significance of Axial Dispersion. Medium Sphere, Re = 1067, Q_w = 179.2 W/m^2, (x,y) in cm.

TIME (min)	RADIAL (60,2)	AXIAL (60,2)	AXIAL/RADIAL %	RADIAL (151,2)	AXIAL (151,2)	AXIAL/RADIAL %
0	0	0		0	0	
5	0.000263	0.000657	249.8	0.005849	0.045645	780.4
10	0.000475	0.000667	140.4	0.004409	0.044436	1007.8
15	0.000709	0.000669	94.4	0.003519	0.043211	1227.9
20	0.000951	0.00067	70.5	0.002926	0.042105	1439.0
25	0.001195	0.000673	56.3	0.002516	0.041154	1635.7
30	0.001432	0.000679	47.4	0.002229	0.040357	1810.5
35	0.001658	0.000689	41.6	0.002033	0.0397	1952.8
40	0.00187	0.000703	37.6	0.001909	0.039166	2051.7
45	0.002067	0.000719	34.8	0.001842	0.038737	2103.0
50	0.002248	0.000738	32.8	0.001823	0.038397	2106.3
55	0.002411	0.000758	31.4	0.001844	0.038134	2068.0
60	0.002559	0.000779	30.4	0.001897	0.037935	1999.7
65	0.002691	0.0008	29.7	0.001977	0.037791	1911.5
70	0.002809	0.000822	29.3	0.002078	0.037692	1813.9
75	0.002913	0.000842	28.9	0.002196	0.037632	1713.7
80	0.003005	0.000862	28.7	0.002327	0.037603	1615.9
85	0.003085	0.000881	28.6	0.002467	0.0376	1524.1
90	0.003155	0.000899	28.5	0.002614	0.037618	1439.1
95	0.003216	0.000916	28.5	0.002764	0.037653	1362.3
100	0.003269	0.000931	28.5	0.002915	0.037702	1293.4
105	0.003315	0.000945	28.5	0.003067	0.037761	1231.2
110	0.003355	0.000957	28.5	0.003216	0.037828	1176.2
115	0.003389	0.000969	28.6	0.003361	0.0379	1127.6
120	0.003419	0.000979	28.6	0.003502	0.037976	1084.4
125	0.003444	0.000988	28.7	0.003637	0.038053	1046.3
130	0.003465	0.000997	28.8	0.003767	0.038131	1012.2
135	0.003484	0.001004	28.8	0.00389	0.038209	982.2
140	0.0035	0.00101	28.9	0.004006	0.038285	955.7
145	0.003513	0.001016	28.9	0.004116	0.038359	931.9
150	0.003525	0.001021	29.0	0.004218	0.03843	911.1
155	0.003535	0.001025	29.0	0.004313	0.038499	892.6
160	0.003543	0.001029	29.0	0.004402	0.038563	876.0
165	0.00355	0.001033	29.1	0.004484	0.038625	861.4
170	0.003556	0.001035	29.1	0.004559	0.038682	848.5
175	0.003561	0.001038	29.1	0.004628	0.038736	837.0
180	0.003565	0.00104	29.2	0.004692	0.038786	826.6
185	0.003569	0.001042	29.2	0.00475	0.038833	817.5
190	0.003572	0.001044	29.2	0.004803	0.038875	809.4
195	0.003575	0.001045	29.2	0.004851	0.038915	802.2
200	0.003577	0.001046	29.2	0.004895	0.038951	795.7
205	0.003579	0.001047	29.3	0.004934	0.038984	790.1
210	0.00358	0.001048	29.3	0.00497	0.039015	785.0

Table 5.3 (Continued).

Time (min)	RADIAL (60,8)	AXIAL (60,8)	AXIAL/RADIAL %	RADIAL (151,8)	AXIAL (151,8)	AXIAL/RADIAL %
0	0	0		0	0	
5	0.000347	0.00063	181.6	0.006898	0.043049	624.1
10	0.000688	0.0006	87.2	0.005796	0.040632	701.0
15	0.001089	0.000552	50.7	0.004914	0.038948	792.6
20	0.00153	0.000495	32.4	0.004196	0.03778	900.4
25	0.001997	0.000437	21.9	0.003617	0.036978	1022.3
30	0.002474	0.000381	15.4	0.003158	0.036438	1153.8
35	0.002949	0.000331	11.2	0.002806	0.036088	1286.1
40	0.003413	0.000288	8.4	0.002544	0.035881	1410.4
45	0.003855	0.000253	6.6	0.002362	0.03578	1514.8
50	0.004272	0.000227	5.3	0.002246	0.03576	1592.2
55	0.004658	0.000209	4.5	0.002188	0.0358	1636.2
60	0.005012	0.000199	4.0	0.002178	0.035887	1647.7
65	0.005333	0.000195	3.7	0.002207	0.036008	1631.5
70	0.00562	0.000197	3.5	0.00227	0.036154	1592.7
75	0.005876	0.000203	3.5	0.002358	0.036319	1540.2
80	0.006102	0.000212	3.5	0.002467	0.036497	1479.4
85	0.0063	0.000224	3.6	0.002592	0.036682	1415.2
90	0.006473	0.000237	3.7	0.002729	0.036872	1351.1
95	0.006622	0.000252	3.8	0.002874	0.037063	1289.6
100	0.006751	0.000267	4.0	0.003024	0.037253	1231.9
105	0.006862	0.000281	4.1	0.003176	0.03744	1178.8
110	0.006957	0.000296	4.3	0.003329	0.037622	1130.1
115	0.007038	0.00031	4.4	0.00348	0.037798	1086.1
120	0.007107	0.000322	4.5	0.003629	0.037967	1046.2
125	0.007165	0.000334	4.7	0.003772	0.038128	1010.8
130	0.007215	0.000346	4.8	0.003911	0.038282	978.8
135	0.007256	0.000356	4.9	0.004043	0.038427	950.5
140	0.007292	0.000365	5.0	0.004169	0.038563	925.0
145	0.007321	0.000373	5.1	0.004289	0.038691	902.1
150	0.007346	0.00038	5.2	0.004401	0.038811	881.9
155	0.007367	0.000386	5.2	0.004506	0.038922	863.8
160	0.007384	0.000392	5.3	0.004603	0.039026	847.8
165	0.007399	0.000397	5.4	0.004694	0.039121	833.4
170	0.007411	0.000401	5.4	0.004778	0.039209	820.6
175	0.007422	0.000405	5.5	0.004856	0.03929	809.1
180	0.00743	0.000409	5.5	0.004927	0.039364	798.9
185	0.007437	0.000411	5.5	0.004992	0.039432	789.9
190	0.007443	0.000414	5.6	0.005052	0.039493	781.7
195	0.007448	0.000416	5.6	0.005106	0.03955	774.6
200	0.007452	0.000418	5.6	0.005155	0.039601	768.2
205	0.007456	0.000419	5.6	0.0052	0.039647	762.4
210	0.007459	0.000421	5.6	0.00524	0.039689	757.4

Table 5.4: Significance of Axial Dispersion. Large Rashig Ring, Re = 2098, Q_w = 179.2 W/m^2, (x,y) in cm.

Time (min)	RADIAL (60,2)	AXIAL (60,2)	AXIAL/RADIAL %	RADIAL (151,2)	AXIAL (151,2)	AXIAL/RADIAL %
0	0	0		0	0	
5	0.000179	0.000684	382.1	0.006024	0.046835	777.5
10	0.000272	0.000703	258.5	0.004564	0.04571	1001.5
15	0.000382	0.000711	186.1	0.003632	0.044589	1227.7
20	0.0005	0.000715	143	0.002985	0.043589	1460.3
25	0.000622	0.000718	115.4	0.002512	0.042736	1701.3
30	0.000741	0.000723	97.6	0.002157	0.042024	1948.3
35	0.000856	0.000728	85.0	0.001886	0.041437	2197.1
40	0.000965	0.000735	76.2	0.001683	0.040957	2433.6
45	0.001066	0.000744	69.8	0.001533	0.040568	2646.3
50	0.001159	0.000754	65.1	0.001427	0.040255	2821.0
55	0.001244	0.000765	61.5	0.001357	0.040006	2948.1
60	0.00132	0.000776	58.8	0.001317	0.039809	3022.7
65	0.001388	0.000787	56.7	0.001302	0.039657	3045.9
70	0.001449	0.000799	55.1	0.001307	0.039541	3025.3
75	0.001503	0.00081	53.9	0.001329	0.039456	2968.8
80	0.001551	0.00082	52.9	0.001364	0.039397	2888.3
85	0.001592	0.000831	52.2	0.001409	0.039359	2793.4
90	0.001629	0.00084	51.6	0.001462	0.039338	2690.7
95	0.001661	0.000849	51.1	0.001521	0.039331	2585.9
100	0.001688	0.000857	50.8	0.001584	0.039335	2483.2
105	0.001712	0.000864	50.5	0.001649	0.039348	2386.2
110	0.001733	0.000871	50.3	0.001715	0.039369	2295.6
115	0.00175	0.000877	50.1	0.001782	0.039394	2210.7
120	0.001766	0.000883	50	0.001848	0.039424	2133.3
125	0.001779	0.000887	49.9	0.001912	0.039456	2063.6
130	0.00179	0.000892	49.8	0.001974	0.03949	2000.5
135	0.0018	0.000896	49.8	0.002034	0.039525	1943.2
140	0.001808	0.000899	49.7	0.002091	0.03956	1891.9
145	0.001815	0.000902	49.7	0.002145	0.039595	1845.9
150	0.001821	0.000905	49.7	0.002196	0.039629	1804.6
155	0.001826	0.000907	49.7	0.002244	0.039662	1767.5
160	0.00183	0.000909	49.7	0.002288	0.039694	1734.9
165	0.001834	0.000911	49.7	0.00233	0.039724	1704.9
170	0.001837	0.000912	49.7	0.002368	0.039753	1678.8
175	0.00184	0.000914	49.7	0.002404	0.03978	1654.7
180	0.001842	0.000915	49.7	0.002436	0.039805	1634.0
185	0.001844	0.000916	49.7	0.002466	0.039829	1615.1
190	0.001845	0.000917	49.7	0.002493	0.039851	1598.5
195	0.001847	0.000918	49.7	0.002518	0.039871	1583.4
200	0.001848	0.000918	49.7	0.00254	0.039889	1570.4

Table 5.4: (Continued).

Time (min)	RADIAL (60,8)	AXIAL (60,8)	AXIAL/RADIAL %	RADIAL (151,8)	AXIAL (151,8)	AXIAL/RADIAL %
0	0	0		0	0	
5	0.000248	0.00067	1770.7	0.006605	0.045476	688.5
10	0.000405	0.000668	722.8	0.005322	0.043713	821.4
15	0.0006	0.00065	457.2	0.004393	0.042351	964.1
20	0.000821	0.000623	328.6	0.003679	0.041318	1123.1
25	0.001058	0.000594	253.1	0.003115	0.040544	1301.6
30	0.001302	0.000565	202.8	0.002667	0.039967	1498.6
35	0.001547	0.000539	168.1	0.002312	0.039541	1710.3
40	0.001786	0.000517	142.7	0.002035	0.039234	1928.0
45	0.002016	0.000499	123.8	0.001822	0.039017	2141.4
50	0.002232	0.000486	109.0	0.001663	0.038871	2337.4
55	0.002433	0.000477	97.6	0.001551	0.03878	2500.3
60	0.002617	0.000471	88.3	0.001476	0.038733	2624.2
65	0.002783	0.00047	80.9	0.001434	0.038719	2700.1
70	0.002933	0.000471	74.7	0.001417	0.038732	2733.4
75	0.003066	0.000474	69.5	0.001422	0.038766	2726.2
80	0.003183	0.00048	65.2	0.001445	0.038814	2686.1
85	0.003286	0.000486	61.6	0.001482	0.038875	2623.1
90	0.003376	0.000494	58.5	0.001529	0.038944	2547.0
95	0.003453	0.000502	55.8	0.001584	0.039018	2463.3
100	0.00352	0.00051	53.5	0.001646	0.039096	2375.2
105	0.003578	0.000517	51.5	0.001712	0.039176	2288.3
110	0.003627	0.000525	49.7	0.00178	0.039257	2205.4
115	0.003669	0.000533	48.2	0.001849	0.039336	2127.4
120	0.003705	0.00054	46.9	0.001918	0.039415	2055.0
125	0.003735	0.000546	45.7	0.001987	0.039491	1987.5
130	0.003761	0.000552	44.7	0.002053	0.039564	1927.1
135	0.003782	0.000557	43.7	0.002118	0.039634	1871.3
140	0.0038	0.000562	43.0	0.00218	0.039701	1821.1
145	0.003816	0.000566	42.3	0.002239	0.039764	1776.0
150	0.003828	0.00057	41.6	0.002295	0.039824	1735.3
155	0.003839	0.000573	41.1	0.002348	0.039879	1698.4
160	0.003848	0.000576	40.6	0.002398	0.039931	1665.2
165	0.003856	0.000579	40.2	0.002444	0.039979	1635.8
170	0.003862	0.000581	39.8	0.002487	0.040024	1609.3
175	0.003867	0.000583	39.5	0.002526	0.040065	1586.1
180	0.003872	0.000585	39.2	0.002563	0.040103	1564.7
185	0.003876	0.000587	38.9	0.002596	0.040138	1546.1
190	0.003879	0.000588	38.7	0.002627	0.04017	1529.1
195	0.003881	0.000589	38.5	0.002655	0.040199	1514.1
200	0.003883	0.00059	38.3	0.00268	0.040225	1500.9

Table 5.5: Significance of Axial Dispersion. Large Rashig Ring, Re = 1067, Q_w = 179.2 W/m^2, (x,y) in cm.

Time (min)	RADIAL (60,2)	AXIAL (60,2)	AXIAL/RADIAL %	RADIAL (151,2)	AXIAL (151,2)	AXIAL/RADIAL %
0	0	0		0	0	
5	0.000306	0.000675	220.6	0.006127	0.046989	766.9
10	0.000499	0.000679	136.1	0.004687	0.045805	977.3
15	0.000715	0.000676	94.5	0.003776	0.044546	1179.7
20	0.000946	0.000672	71.0	0.003161	0.043401	1373.0
25	0.001183	0.000671	56.7	0.002727	0.042409	1555.2
30	0.001417	0.000674	47.6	0.002414	0.041571	1722.1
35	0.001643	0.000682	41.5	0.002191	0.040872	1865.4
40	0.001857	0.000693	37.3	0.002039	0.040297	1976.3
45	0.002058	0.000709	34.5	0.001946	0.039828	2046.7
50	0.002243	0.000727	32.4	0.001901	0.039451	2075.3
55	0.002413	0.000748	31.0	0.001898	0.039151	2062.8
60	0.002567	0.000769	30.0	0.001929	0.038918	2017.5
65	0.002705	0.000792	29.3	0.001989	0.038742	1947.8
70	0.002829	0.000815	28.8	0.002073	0.038614	1862.7
75	0.002939	0.000837	28.5	0.002176	0.038527	1770.5
80	0.003037	0.000859	28.3	0.002295	0.038474	1676.4
85	0.003123	0.000879	28.1	0.002426	0.03845	1584.9
90	0.003198	0.000899	28.1	0.002566	0.03845	1498.4
95	0.003264	0.000917	28.1	0.002711	0.038469	1419.0
100	0.003322	0.000934	28.1	0.00286	0.038505	1346.3
105	0.003372	0.00095	28.2	0.003011	0.038553	1280.4
110	0.003415	0.000964	28.2	0.003161	0.038611	1221.5
115	0.003453	0.000977	28.3	0.003308	0.038676	1169.2
120	0.003485	0.000989	28.4	0.003453	0.038747	1122.1
125	0.003513	0.000999	28.4	0.003593	0.03882	1080.4
130	0.003537	0.001008	28.5	0.003728	0.038896	1043.3
135	0.003558	0.001017	28.6	0.003857	0.038973	1010.4
140	0.003575	0.001024	28.6	0.00398	0.039049	981.1
145	0.00359	0.001031	28.7	0.004097	0.039124	954.9
150	0.003603	0.001037	28.8	0.004206	0.039197	931.9
155	0.003614	0.001042	28.8	0.004309	0.039267	911.3
160	0.003624	0.001046	28.9	0.004405	0.039335	893.0
165	0.003632	0.00105	28.9	0.004494	0.039399	876.7
170	0.003639	0.001054	29.0	0.004577	0.03946	862.1
175	0.003644	0.001057	29.0	0.004653	0.039517	849.3
180	0.003649	0.001059	29.0	0.004724	0.039571	837.7
185	0.003654	0.001062	29.1	0.004788	0.039621	827.5
190	0.003657	0.001064	29.1	0.004847	0.039668	818.4
195	0.00366	0.001065	29.1	0.004901	0.039711	810.3
200	0.003663	0.001067	29.1	0.004951	0.03975	802.9
205	0.003665	0.001068	29.1	0.004995	0.039787	796.5
210	0.003667	0.001069	29.2	0.005036	0.039821	790.7

Table 5.5: (Continued).

Time (min)	RADIAL (60,8)	AXIAL (60,8)	AXIAL/RADIAL %	RADIAL (151,8)	AXIAL (151,8)	AXIAL/RADIAL %
0	0	0		0	0	
5	0.000692	0.000656	94.8	0.007449	0.044456	596.8
10	0.000965	0.00062	64.2	0.00634	0.042022	662.8
15	0.001306	0.000567	43.4	0.005422	0.04028	742.9
20	0.001701	0.000504	29.6	0.004664	0.03906	837.5
25	0.002131	0.00044	20.6	0.00404	0.038209	945.8
30	0.002581	0.000379	14.7	0.003536	0.037623	1064.0
35	0.003036	0.000324	10.7	0.003137	0.037231	1186.8
40	0.003486	0.000277	7.9	0.002831	0.036982	1306.3
45	0.003921	0.00024	6.1	0.002605	0.036841	1414.2
50	0.004333	0.000211	4.9	0.00245	0.036783	1501.3
55	0.004719	0.000192	4.1	0.002354	0.036789	1562.8
60	0.005075	0.00018	3.5	0.002309	0.036842	1595.6
65	0.005399	0.000176	3.3	0.002308	0.036933	1600.2
70	0.005691	0.000178	3.1	0.002342	0.037052	1582.1
75	0.005952	0.000185	3.1	0.002407	0.037193	1545.2
80	0.006184	0.000195	3.2	0.002495	0.037348	1496.9
85	0.006388	0.000208	3.3	0.002604	0.037515	1440.7
90	0.006566	0.000223	3.4	0.002727	0.037688	1382.0
95	0.006721	0.000239	3.6	0.002861	0.037866	1323.5
100	0.006856	0.000256	3.7	0.003003	0.038044	1266.9
105	0.006971	0.000272	3.9	0.00315	0.038222	1213.4
110	0.007071	0.000288	4.1	0.003299	0.038396	1163.9
115	0.007156	0.000304	4.2	0.003449	0.038567	1118.2
120	0.007229	0.000318	4.4	0.003598	0.038733	1076.5
125	0.00729	0.000332	4.6	0.003743	0.038892	1039.1
130	0.007343	0.000344	4.7	0.003885	0.039045	1005.0
135	0.007387	0.000355	4.8	0.004021	0.03919	974.6
140	0.007425	0.000365	4.9	0.004152	0.039328	947.2
145	0.007456	0.000375	5.0	0.004277	0.039459	922.6
150	0.007483	0.000383	5.1	0.004395	0.039581	900.6
155	0.007506	0.00039	5.2	0.004506	0.039696	881.0
160	0.007525	0.000397	5.3	0.004611	0.039803	863.2
165	0.00754	0.000402	5.3	0.004708	0.039902	847.5
170	0.007554	0.000407	5.4	0.004799	0.039995	833.4
175	0.007565	0.000412	5.4	0.004883	0.04008	820.8
180	0.007574	0.000415	5.5	0.004961	0.040158	809.5
185	0.007582	0.000419	5.5	0.005032	0.04023	799.5
190	0.007589	0.000422	5.6	0.005098	0.040297	790.4
195	0.007594	0.000424	5.6	0.005158	0.040357	782.4
200	0.007599	0.000426	5.6	0.005212	0.040412	775.4
205	0.007603	0.000428	5.6	0.005262	0.040462	768.9
210	0.007606	0.00043	5.7	0.005307	0.040508	763.3

Table 5.6: Significance of Axial Dispersion. Large Rashig Ring, Re = 445, Q_w = 179.2 W/m^2, (x,y) in cm.

Time (min)	RADIAL (60,2)	AXIAL (60,2)	AXIAL/RADIAL %	RADIAL (151,2)	AXIAL (151,2)	AXIAL/RADIAL %
0	0	0		0	0	
5	0.000533	0.000684	128.3	0.006149	0.047429	771.3
10	0.001146	0.000646	56.4	0.005108	0.046865	917.5
15	0.001644	0.00059	35.9	0.004445	0.045527	1024.2
20	0.002149	0.000544	25.3	0.004012	0.044094	1099.1
25	0.00267	0.00051	19.1	0.003727	0.042755	1147.2
30	0.003195	0.000491	15.4	0.003547	0.041568	1171.9
35	0.003712	0.000487	13.1	0.003446	0.04054	1176.4
40	0.004212	0.000497	11.8	0.003412	0.039662	1162.4
45	0.004688	0.000518	11.0	0.003434	0.038919	1133.3
50	0.005134	0.00055	10.7	0.003508	0.038298	1091.7
55	0.00555	0.00059	10.6	0.003629	0.037785	1041.2
60	0.005932	0.000637	10.7	0.003791	0.037369	985.7
65	0.006281	0.000687	10.9	0.003992	0.03704	927.9
70	0.006598	0.000741	11.2	0.004226	0.036787	870.5
75	0.006883	0.000795	11.6	0.00449	0.036601	815.2
80	0.007139	0.00085	11.9	0.004779	0.036476	763.3
85	0.007368	0.000903	12.3	0.005088	0.036403	715.5
90	0.007571	0.000955	12.6	0.005414	0.036376	671.9
95	0.007751	0.001005	13.0	0.005753	0.036389	632.5
100	0.007909	0.001052	13.3	0.0061	0.036435	597.3
105	0.008049	0.001096	13.6	0.006451	0.03651	566.0
110	0.008171	0.001137	13.9	0.006805	0.036609	538.0
115	0.008278	0.001175	14.2	0.007157	0.036727	513.2
120	0.008371	0.00121	14.5	0.007505	0.03686	491.1
125	0.008453	0.001242	14.7	0.007846	0.037005	471.6
130	0.008523	0.00127	14.9	0.008179	0.037159	454.3
135	0.008585	0.001296	15.1	0.008502	0.037318	438.9
140	0.008638	0.00132	15.3	0.008813	0.037481	425.3
145	0.008684	0.001341	15.4	0.009111	0.037645	413.2
150	0.008724	0.00136	15.6	0.009396	0.037807	402.4
155	0.008758	0.001377	15.7	0.009667	0.037968	392.8
160	0.008788	0.001392	15.8	0.009923	0.038125	384.2
165	0.008813	0.001405	15.9	0.010165	0.038277	376.6
170	0.008835	0.001417	16.0	0.010391	0.038424	369.8
175	0.008854	0.001427	16.1	0.010604	0.038565	363.7
180	0.00887	0.001436	16.2	0.010802	0.0387	358.3
185	0.008884	0.001444	16.3	0.010986	0.038827	353.4
190	0.008896	0.001451	16.3	0.011157	0.038947	349.1
195	0.008906	0.001457	16.4	0.011315	0.03906	345.2
200	0.008915	0.001463	16.4	0.01146	0.039166	341.8
205	0.008922	0.001467	16.4	0.011594	0.039265	338.7
210	0.008929	0.001472	16.5	0.011717	0.039357	335.9

Table 5.6: (Continued).

Time (min)	RADIAL (60,8)	AXIAL (60,8)	AXIAL/RADIAL %	RADIAL (151,8)	AXIAL (151,8)	AXIAL/RADIAL %
0	0	0		0	0	
5	0.003848	0.000678	17.62	0.011147	0.042419	380.5
10	0.004351	0.000569	13.08	0.010852	0.038878	358.3
15	0.004806	0.00041	8.53	0.010069	0.03633	360.8
20	0.005382	0.000239	4.44	0.009183	0.034644	377.3
25	0.006074	0.000066	1.09	0.008338	0.03356	402.5
30	0.006851	-0.0001	1.46	0.007592	0.032891	433.2
35	0.007683	-0.00025	3.27	0.006964	0.032511	466.8
40	0.008542	-0.00038	4.50	0.006457	0.032334	500.8
45	0.009402	-0.00049	5.25	0.006065	0.032302	532.6
50	0.010243	-0.00058	5.66	0.00578	0.032376	560.1
55	0.01105	-0.00064	5.82	0.005591	0.03253	581.8
60	0.011812	-0.00068	5.79	0.00549	0.032743	596.4
65	0.012522	-0.00071	5.64	0.005465	0.033002	603.9
70	0.013174	-0.00071	5.40	0.005509	0.033296	604.4
75	0.013768	-0.0007	5.10	0.005611	0.033616	599.1
80	0.014303	-0.00068	4.76	0.005764	0.033955	589.1
85	0.014782	-0.00065	4.40	0.005961	0.034308	575.5
90	0.015207	-0.00062	4.05	0.006192	0.034671	559.9
95	0.015582	-0.00058	3.70	0.006453	0.035038	543.0
100	0.015911	-0.00053	3.35	0.006737	0.035408	525.6
105	0.016199	-0.00049	3.02	0.007038	0.035776	508.3
110	0.01645	-0.00045	2.71	0.007352	0.036141	491.6
115	0.016667	-0.0004	2.42	0.007673	0.0365	475.7
120	0.016855	-0.00036	2.16	0.007999	0.036852	460.7
125	0.017016	-0.00033	1.92	0.008324	0.037193	446.8
130	0.017155	-0.00029	1.69	0.008646	0.037525	434.0
135	0.017274	-0.00026	1.49	0.008963	0.037844	422.2
140	0.017376	-0.00023	1.30	0.009272	0.038151	411.5
145	0.017463	-0.0002	1.14	0.009572	0.038444	401.6
150	0.017537	-0.00017	0.99	0.009861	0.038723	392.7
155	0.0176	-0.00015	0.86	0.010137	0.038988	384.6
160	0.017654	-0.00013	0.74	0.010401	0.039239	377.3
165	0.017699	-0.00011	0.64	0.010651	0.039476	370.6
170	0.017738	-9.7E-05	0.55	0.010887	0.039698	364.6
175	0.017771	-8.3E-05	0.47	0.011109	0.039906	359.2
180	0.017799	-7.1E-05	0.40	0.011317	0.0401	354.3
185	0.017822	-0.00006	0.34	0.011511	0.040281	349.9
190	0.017842	-0.00005	0.28	0.011692	0.04045	346.0
195	0.017859	-4.2E-05	0.24	0.01186	0.040605	342.4
200	0.017873	-3.5E-05	0.20	0.012015	0.040749	339.2
205	0.017885	-2.8E-05	0.16	0.012158	0.040882	336.3
210	0.017896	-2.3E-05	0.13	0.012289	0.041004	333.7

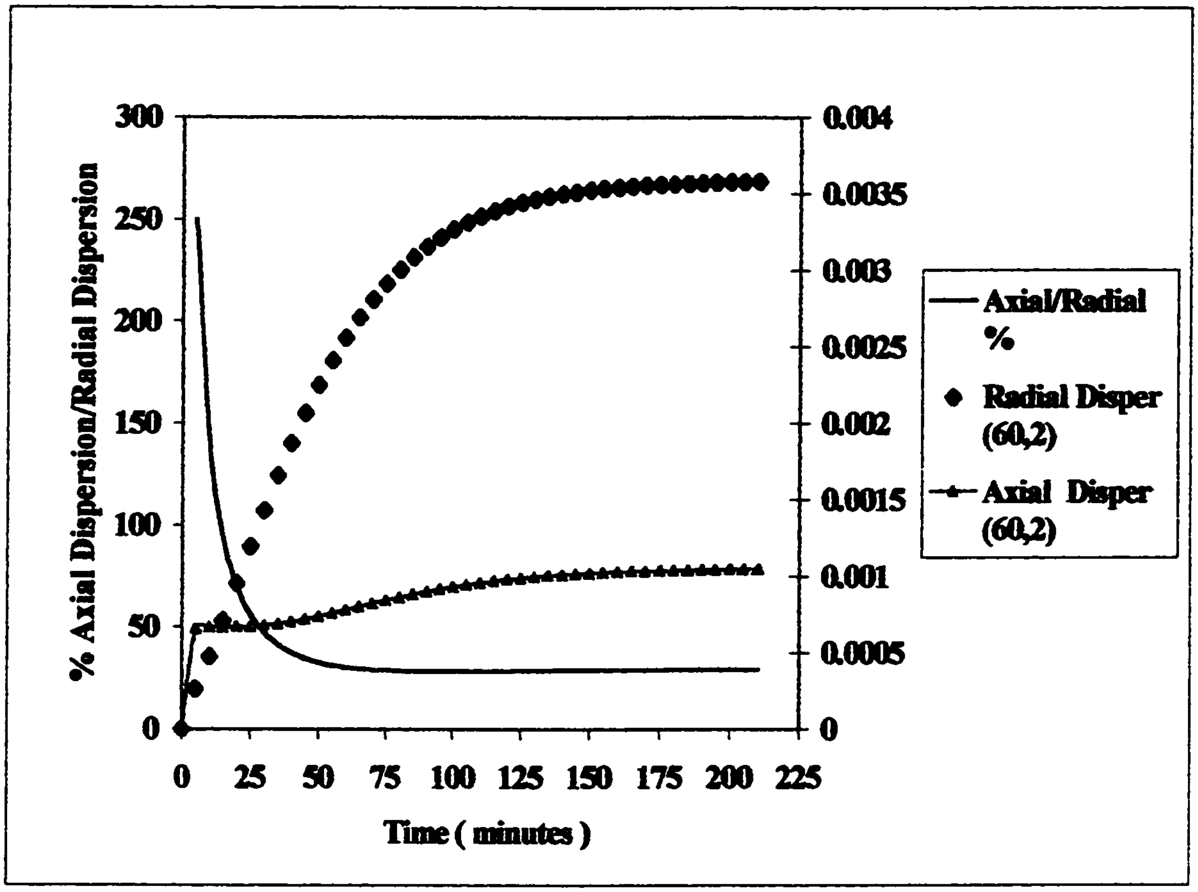


Figure 5.75: Significance of Axial Dispersion for Medium Sphere; $d_p = 3.87$ cm. $x = 60$ cm & $y = 2$ cm, Re = 1067, $Q_w = 179.2\ W/m^2$.

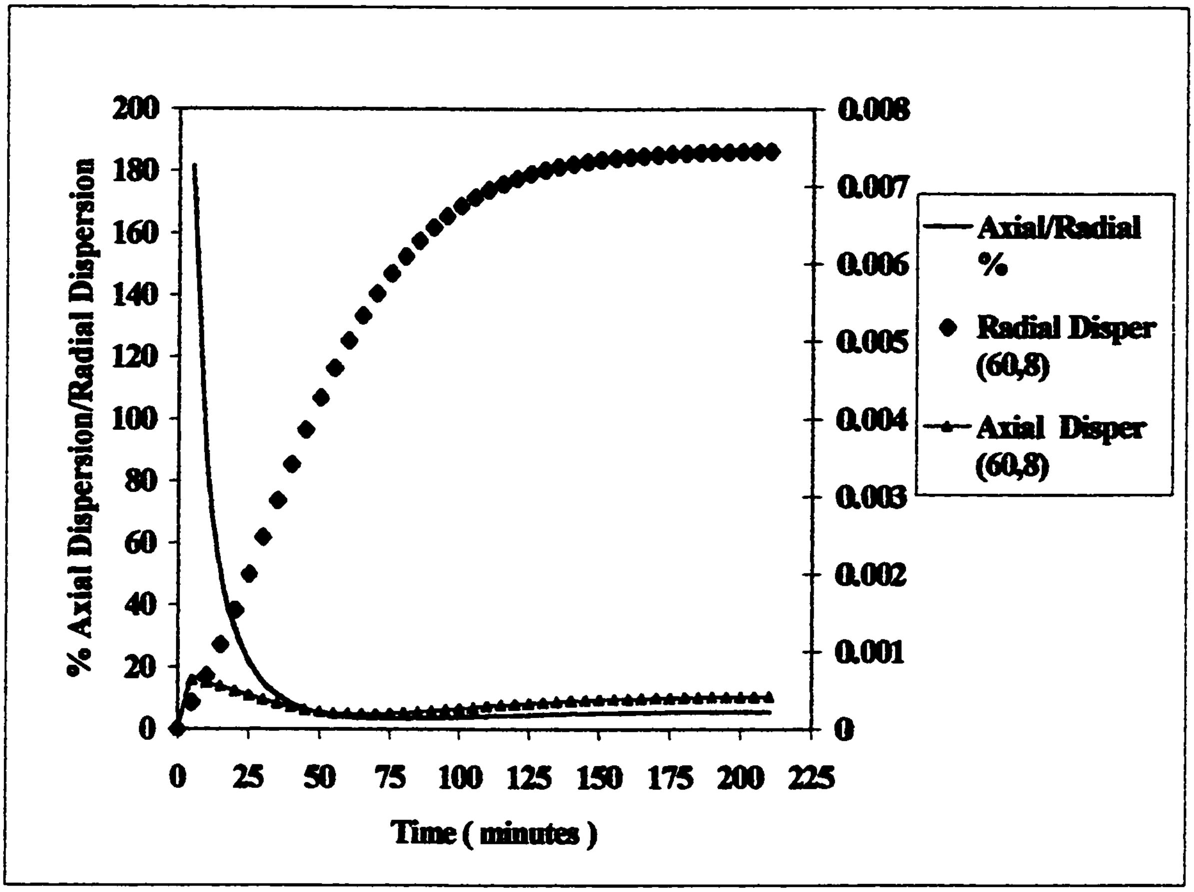


Figure 5.76: Significance of Axial Dispersion for Medium Sphere; $d_p = 3.87$ cm. $x = 60$ cm & $y = 8$ cm, $Re = 1067$, $Q_w = 179.2$ W/m^2.

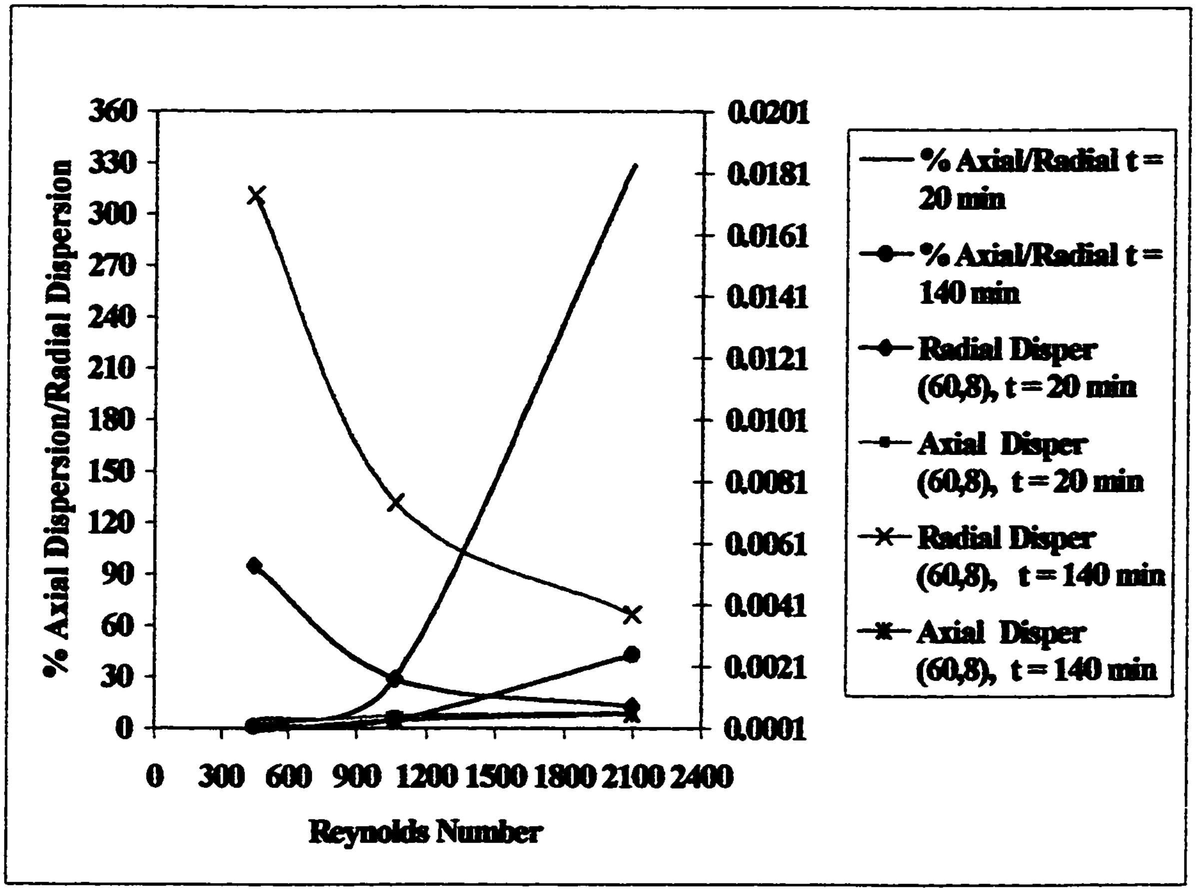


Figure 5.77: Effect of Reynolds Number on Axial Dispersion for Large Rashig Ring, d_p = 3.87 cm, x = 60 cm, y = 8 cm Q_w = 179.2 W/m^2.

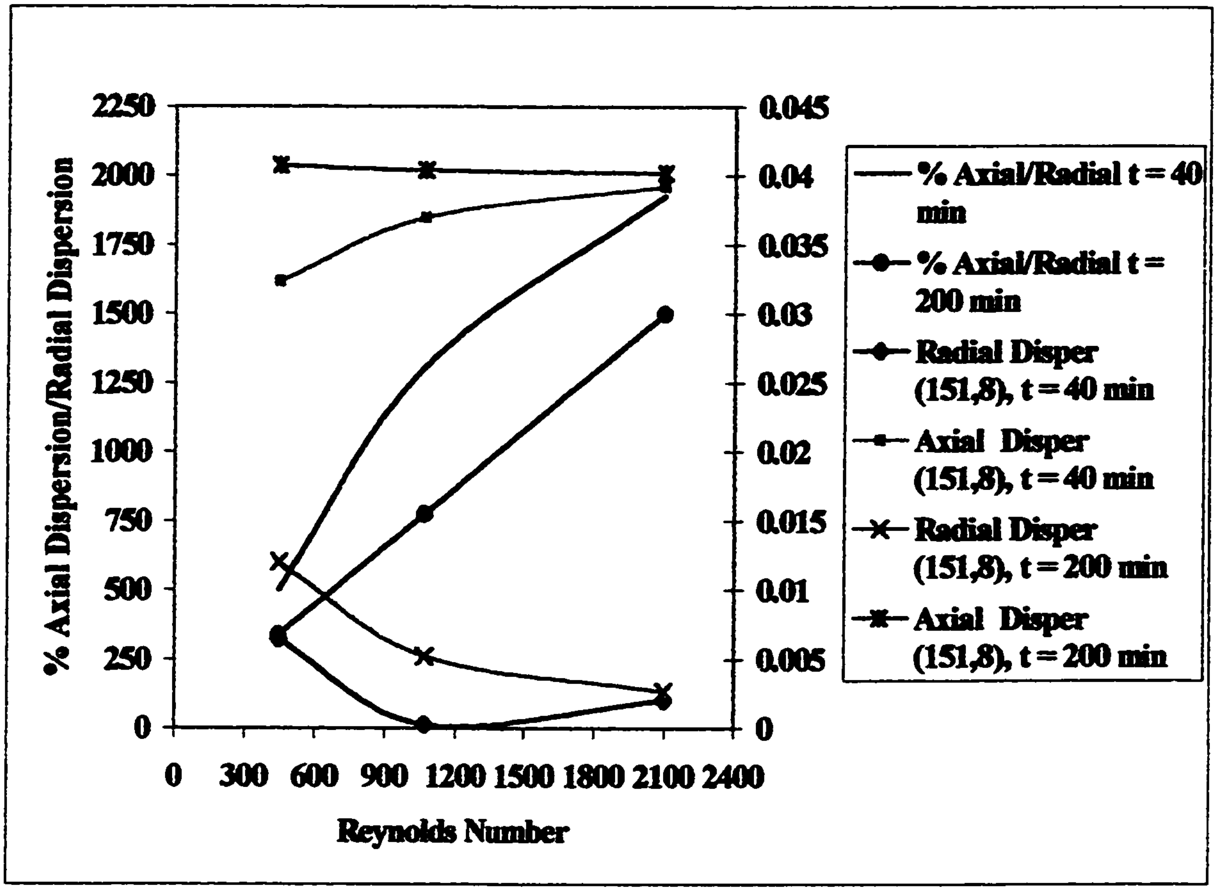


Figure 5.78: Effect of Reynolds Number on Axial Dispersion for Large Rashig Ring, d_p = 3.87 cm, x = 151 cm, y = 8 cm Q_w = 179.2 W/m^2.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

A study of transient forced convection heat transfer in a rectangular packed duct with asymmetric heating has been conducted. The study involved both experimental and theoretical works. The problem was modeled based on the one phase pseudo-homogeneous model. In this experimental and theoretical investigation, several experimental runs have been done for different types of packing with different heat flux and airflow rates. The mathematical pseudo-homogeneous model has been solved numerically using the orthogonal collocation method. The effect of the shape and size of packing on the heat transfer and the transient time was studied. The influence of Reynolds number on heat transfer and steady state time was also considered. The significance of axial dispersion on convection heat transfer in packed ducts with asymmetric heating was analyzed. The findings of the present work can be summarized as follows.

1. The predicted data generated by solving the pseudo-homogeneous model is in a good agreement with those obtained experimentally. The maximum deviation is 8 %.

2. The proposed pseudo-homogeneous model is good for representing transient convection heat transfer in a rectangular packed duct with asymmetric heating.
3. The shape of the packing has no considerable effect on the time required to reach steady state or the heat transfer.
4. The size of packing has no effect on the time needed to reach steady state. However, it can affect slightly the heat transfer.
5. Rashig Ring gives less pressure drop compared to spherical packing. It is preferable to use Rashig Ring in packed ducts.
6. The airflow rate plays a major role in the process of heat transfer in packed ducts. The transient heat transfer is highly affected by Reynolds number.
7. The axial dispersion is significant in describing transient forced convection heat transfer in a rectangular packed duct with asymmetric heating. The degree of significance depends highly on Reynolds number.
8. The significance of axial dispersion decreases as the system reaches steady state. In modeling steady state convection heat transfer in a packed duct with asymmetric heating, axial dispersion can be neglected.

Recommendations:

1. Model the problem of transient forced convection heat transfer in a rectangular packed duct with asymmetric heating by using the two-phase model. The data produced should be compared with those predicted by the one phase pseudo-homogeneous model.
2. Model the problem for different boundary conditions.
3. Study the problem for wider range of Reynolds number.
4. Analyze the problem for different Prandtl number.
5. Study the effect of reducing the separation distance between the top and bottom walls on the transient heat transfer process.
6. Take into account the wall effect, as d_e/d_p is large.

NOMENCLATURE

a_p	Surface area of solid particle per unit volume of the bed.
$A, B, \hat{C}, \& M$	Parameters in Zehner and Schlunder relation (4.15).
$Ax_{ik}, Ay_{jk}, Bx_{ik} \& By_{jk}$	First and second derivative matrix parameters for Shifted Legendre Polynomials.
Bi_s	Solid/wall Biot number
C	Heat Capacity Ratio.
C_f	Specific heat of the fluid.
C_s	Specific heat of the solid.
d_e	Equivalent diameter of the duct.
d_p	Equivalent diameter of the particle.
G	Mass flux.
H	The height of the duct.
k_{ea}	Effective axial thermal conductivity.
k_{ey}	Effective radial thermal conductivity.
k_f	Fluid thermal conductivity.
k_{dy}	Dynamic thermal conductivity.
k_s	Solid thermal conductivity.
k_{st}	Stagnant thermal conductivity.

L	Length of the duct.
$\dot{m}$	Mass velocity.
N_i	Number of particles in a bed diameter (d_e/d_p).
N_s	Interphase heat transfer group.
Nu_{fs}	Fluid/Solid Nusselt number.
Pe_a	Axial Peclet number. $Pe_a = \dfrac{GC_f d_p}{k_{ea}}$
Pe_y	Radial Peclet number. $Pe_y = \dfrac{GC_f d_p}{k_{ey}}$
Pe_p^s	Peclet number based on the superficial velocity.
Pr	Prandtl number.
q_w	Heat flux.
Re	Reynolds number. $Re = \dfrac{Gd_p}{\mu}$
Re_p	Modified Reynolds number. $Re_p = \dfrac{\rho \upsilon_\infty d_p}{(1-\varepsilon)\mu}$
$S(\ )$	Temperature vector of Boundary nodes.
t	Time.
T	Temperature.
T_b	Bulk temperature.
T_o	Inlet temperature.

T_R	Reference temperature.
T_w	Wall temperature.
w	Width of the duct.
x	Duct axial coordinate.
y	Duct radial coordinate.
Z( )	Temperature vector of interior nodes.

Greek Symbols:

α_x, α_y	Aspect ratio in the axial and radial direction.
ε	Bed void fraction.
ρ_f	Density of the fluid air.
ρ_s	Density of the solid.
υ_∞	Superficial velocity of fluid air.
μ	Viscosity of the fluid air.
θ	Dimensionless temperature. $(\frac{T-T_R}{T_o-T_R})$
ϕ_s	Shape factor for non-spherical packing.
ξ	Dimensionless axial coordinate. $(\frac{x}{L})$

η	Dimensionless radial coordinate. $(\frac{y}{H})$
τ	Dimensionless time. $\tau = \frac{tGC_f}{\left[d_p(1-\varepsilon)\rho_s C_s\right]}$

Subscripts:

a	Axial.
b	Bulk.
dy	Dynamic.
e	Equivalent.
ea	Effective axial.
ey	Effective radial.
f	Fluid.
i	Local.
p	Particle.
y	Radial.
s	Solid.
st	Stagnant.
w	Wall.

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APPENIX A

EXPERIMENTAL DATA

Table A1.1: Experimental Data for Small Sphere, $d_p = 2.9$ cm.
Run # 1: Re = 935.4 $Q_w = 243.4$ W/m^2 $T_{amb} = 26.5$ °C.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	25.81	25.81	25.61	25.76	25.61	25.71	25.81	25.81	25.9	25.9	26.1	25.86	26.15	25.95	26.05	26.15
5	26.23	26.08	25.9	26.41	26.17	26.08	26.51	26.41	26.15	26.61	26.56	26.15	26.05	26.61	27.3	27.84
10	26.12	25.92	25.74	26.51	26.12	25.92	26.56	26.33	26.15	26.98	26.79	26.1	25.81	26.89	28.13	29.17
15	26.39	26.05	25.86	27.08	26.35	26.1	27.08	26.74	26.39	27.84	27.33	26.79	26.1	27.51	28.94	30.59
20	26.49	26	26	27.33	26.64	26.2	27.56	26.92	26.76	28.45	27.86	27.1	26.51	28.45	29.96	32.15
25	26.59	26.1	25.95	27.46	26.59	26.25	27.61	26.92	26.74	28.71	28.17	26.84	26.25	28.66	30.08	32.64
30	26.46	26.23	25.88	27.54	26.51	26.12	27.79	26.95	26.71	28.81	28.2	27.2	26.12	28.81	30.27	33.2
35	26.54	26.1	25.95	27.64	26.54	26.1	27.89	27.02	26.56	29.13	28.4	27.2	25.9	29.08	30.35	33.96
40	26.66	26.27	26.02	28	26.71	26.27	28.2	27.05	26.79	29.38	28.56	27.33	26.25	29.56	30.94	34.81
45	26.46	26.27	26.02	27.76	26.64	26.33	28.05	27.02	26.76	29.59	28.64	27.4	26.17	29.74	31.12	35.06
50	26.64	26.02	25.88	27.91	26.74	26.08	28.13	27.13	26.76	29.69	28.69	27.3	26.38	29.91	31.17	35.5
55	26.49	26.2	25.86	27.89	26.86	26.3	28.25	27.3	26.84	29.94	28.99	27.79	26.05	30.17	31.35	35.89
60	26.91	26.33	26.23	28.25	27	26.51	28.51	27.51	27.05	30.2	29.15	28.05	26.46	30.45	31.58	36.58
65	26.54	26.08	25.92	28.08	26.74	26.27	28.42	27.33	26.71	30.1	29.1	27.66	26.33	30.52	31.64	36.5
70	26.79	26.35	26.3	28.42	26.92	26.59	28.56	27.66	27.05	30.35	29.3	27.66	26.46	30.76	31.99	36.88
75	26.74	26.27	26.02	28.13	27.08	26.44	28.48	27.42	27.08	30.3	29.25	27.86	26.46	30.86	31.79	37.19
80	26.64	26.17	26.02	28.23	26.98	26.44	28.71	27.56	26.71	30.4	29.2	27.59	25.79	31.01	31.69	37.19

Table A1.1: (Continued).

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
85	26.92	26.59	26.25	28.48	27.08	26.54	28.94	27.66	27.13	30.52	29.61	27.81	26.79	31.17	32.15	37.61
90	26.76	26.23	26.33	28.35	27.1	26.41	28.74	27.59	27.1	30.69	29.54	28.02	26.56	31.35	32.13	37.8
95	26.71	26.46	26.08	28.15	27.1	26.46	28.76	27.51	27.1	30.66	29.45	27.86	26.23	31.2	32.17	37.75
100	26.84	26.44	26.3	28.49	27.15	26.54	28.84	27.59	27.25	30.74	29.71	28.02	26.38	31.4	32.28	37.85
105	26.92	26.44	26.25	28.38	27.02	26.49	28.81	27.51	27.02	30.66	29.66	28	26.64	31.38	32.3	37.95
110	27.02	26.54	26.3	28.61	27.37	26.79	29.08	27.94	27.37	31.12	29.91	28.56	26.69	31.84	32.45	38.41
115	27.02	26.41	26.27	28.56	27.23	26.66	28.96	27.71	27	30.91	29.69	28.1	26.51	31.58	32.28	38.03
120	27.02	26.74	26.35	28.48	27.13	26.64	28.86	27.95	27.33	30.96	29.69	28.2	26.51	31.66	32.22	38.36
125	27.17	26.71	26.56	28.76	27.37	26.81	29.25	28.2	27.4	31.15	30.04	28.49	26.46	31.91	32.64	38.44
130	27.2	26.74	26.54	28.79	27.4	26.84	29.13	28.08	27.33	31.08	29.81	28.17	26.89	31.99	32.55	38.46
135	26.92	26.44	26.35	28.59	27.08	26.64	28.89	27.79	27.37	30.84	29.66	28.08	26.44	31.79	32.06	38.17
140	26.98	26.69	26.49	28.76	27.33	26.74	29.27	27.91	27.33	31.15	29.74	28.35	26.74	31.86	32.45	38.51
145	26.91	26.51	26.17	28.49	27.2	26.71	28.89	27.69	27.15	30.84	29.56	28.02	26.25	31.76	32.11	38.39
150	27.1	26.71	26.61	28.74	27.44	26.95	29.13	27.94	27.49	30.99	29.86	28.17	26.51	32.01	32.47	38.41

Table A1.2: Experimental Data for Small Sphere, $d_p = 2.9$ cm.
Run # 2: Re = 756 $Q_w = 243.4$ W/m^2 $T_{amb} = 26.5$ °C.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	25.54	25.44	25.39	25.44	25.49	25.59	25.59	25.59	25.88	25.92	25.98	26.02	25.64	26.02	25.92	25.98
5	25.9	25.61	25.66	25.9	25.66	25.71	25.81	25.95	25.79	26.2	26.3	26.08	25.88	26.15	27.02	27.44
10	26.08	25.79	25.69	26.56	26.02	25.74	26.41	26.08	26.12	27.17	26.71	26.17	26.12	26.76	28.42	29.17
15	26.15	25.81	25.86	27.1	26.2	25.9	27	26.25	26.25	27.81	27.4	26.71	25.81	27.4	29.27	30.86
20	26.54	25.95	25.76	27.35	26.44	26.05	27.49	26.81	26.41	28.48	27.76	26.81	26.1	27.91	30.23	32.35
25	26.46	26.02	25.86	27.71	26.41	26.08	27.81	26.91	26.64	29.1	28.3	27.08	26.15	28.59	30.94	33.38
30	26.71	26.02	25.84	27.86	26.66	26.12	28.13	27.08	26.71	29.48	28.56	27.25	26.15	29.05	31.48	34.4
35	26.69	26.08	25.84	28.02	26.79	26.08	28.54	27.27	26.71	29.89	29	27.49	26.08	29.51	32.04	35.5
40	26.69	25.95	26	28.25	26.95	26.3	28.54	27.4	26.81	30.38	29.05	27.61	26.23	29.89	32.13	36.31
45	26.74	26.15	25.98	28.45	26.89	26.3	28.89	27.59	27	30.61	29.35	27.91	26.15	30.23	32.55	37
50	26.69	26.2	25.9	28.54	26.98	26.39	28.99	27.64	26.98	30.86	29.64	27.79	26.05	30.61	32.89	37.46
55	26.74	26.35	26.05	28.69	27.02	26.44	29.15	27.74	27.05	31.33	29.59	28.08	26.3	30.71	32.89	38.17
60	26.89	26.3	26	28.74	27.17	26.44	29.25	27.79	26.98	31.58	29.89	27.91	26.17	31.1	33.17	38.41
65	26.84	26.12	26.02	28.89	27.17	26.27	29.38	27.94	27.17	31.86	30.13	27.95	26.02	31.4	33.42	38.95
70	26.92	26.2	26.05	28.84	27.23	26.44	29.33	27.98	26.98	31.81	29.99	28.33	26.12	31.52	33.55	39.17
75	26.98	26.39	26.05	29.02	27.23	26.35	29.5	28.02	27.17	32.06	30.23	28.2	26.17	31.96	33.74	39.64
80	26.89	26.23	26.12	29.02	27.33	26.54	29.42	28.02	27.23	32.13	30.27	28.42	26.46	31.96	33.79	39.71
85	26.95	26.33	26.1	29.05	27.35	26.56	29.66	28.05	27.3	32.2	30.35	28.17	26.35	32.11	33.81	40.16
90	26.84	26.35	26.15	29.08	27.4	26.49	29.54	28.08	27.27	32.09	30.4	28.17	26.15	32.13	33.94	40.14
95	26.91	26.33	26.17	29.15	27.4	26.61	29.86	28.2	27.3	32.53	30.4	28.59	26.27	32.35	34.01	40.37
100	27.02	26.44	26.05	29.13	27.4	26.49	29.64	27.94	27.27	32.55	30.33	28.48	26.25	32.55	33.84	40.47
105	26.95	26.27	26.08	29.25	27.35	26.46	29.71	28.05	27.15	32.63	30.52	28.45	26.12	32.63	34.06	40.78
110	26.92	26.2	26	29.08	27.44	26.54	29.69	28.08	27.37	32.17	30.48	28.33	26.49	32.64	33.94	40.67
115	26.98	26.44	26	29.23	27.37	26.64	29.89	28.23	27.23	32.33	30.64	28.42	26.2	32.69	33.99	41.01
120	27.02	26.3	26.15	29.13	27.46	26.54	29.79	28.08	27.33	32.63	30.52	28.38	26.25	32.89	33.94	40.89

Table A1.2: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	$T_w 1$	$T_w 2$
125	27.02	26.44	26.15	29.27	27.51	26.64	29.94	28.17	27.37	32.84	30.84	28.61	26.3	32.89	34.19	40.99
130	27.02	26.33	26.17	29.1	27.42	26.59	29.81	28.05	27.37	32.63	30.76	28.45	26.38	32.94	34.09	41.04
135	27.08	26.27	26.12	29.38	27.42	26.59	29.86	28.2	27.49	32.86	30.86	28.54	26.51	33.01	34.2	41.29
140	26.92	26.44	26.15	29.23	27.51	26.59	29.79	28.27	27.35	32.74	30.69	28.42	26.25	33.06	34.16	41.19
145	27.13	26.44	26.2	29.27	27.42	26.69	29.89	28.23	27.23	32.79	30.84	28.66	26.3	33.16	34.14	41.26
150	26.98	26.49	26.2	29.38	27.46	26.59	30.04	28.17	27.4	32.79	30.64	28.59	26.25	33.01	34.09	41.16
155	27.15	26.56	26.17	29.25	27.4	26.71	29.91	28.15	27.69	32.91	30.74	28.74	26.51	33.25	34.35	41.34
160	27.1	26.56	26.12	29.15	27.49	26.71	29.91	28.15	27.4	32.64	30.64	28.45	26.17	33.11	34.11	41.16
165	27.1	26.51	26.23	29.35	27.44	26.81	30.01	28.35	27.49	32.89	30.89	28.84	26.54	33.3	34.19	41.39
170	27.05	26.39	26.1	29.33	27.49	26.69	29.84	28.23	27.37	32.89	30.79	28.51	26.59	33.35	34.3	41.26
175	27.05	26.54	26.2	29.23	27.49	26.74	29.99	28.27	27.35	32.91	30.74	28.69	26.38	33.2	34.25	41.34
180	27.08	26.59	26.2	29.23	27.54	26.64	30.04	28.42	27.44	32.69	30.84	28.61	26.49	33.25	34.3	41.31
185	27.17	26.49	26.2	29.33	27.46	26.79	29.86	28.38	27.46	32.91	30.76	28.76	26.38	33.33	34.2	41.46
190	27.05	26.39	26.2	29.27	27.49	26.71	29.99	28.27	27.46	32.79	30.79	28.76	26.64	33.35	34.35	41.19

Table A1.3: Experimental Data for Small Sphere, $d_p = 2.9$ cm.
Run # 3: Re = 538.2 $Q_w = 243.4$ W/m^2 $T_{amb} = 27.5$ °C.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w1	T_w2
0	26.66	26.71	26.71	26.86	26.71	26.66	26.76	26.86	27.1	27.3	27.3	27.35	26.59	27.3	27.35	27.35
5	26.81	26.71	26.71	27	26.86	26.81	26.91	26.81	27.13	27.51	27.37	27.33	26.69	27.51	28.33	28.81
10	27.08	26.74	26.74	27.79	26.98	26.89	27.59	27.13	27.15	28.17	27.89	27.44	26.81	27.79	29.74	30.61
15	27.33	26.89	26.64	28.38	27.27	27.02	28.42	27.56	27.25	29	28.59	27.76	27.05	28.59	31.08	32.25
20	27.37	26.86	26.61	28.86	27.46	27.13	28.86	27.95	27.64	29.64	29.08	27.98	26.89	29.13	32.09	33.84
25	27.64	27.05	26.86	29.3	27.91	27.2	29.4	28.4	27.74	30.45	29.69	28.42	27.02	29.69	32.96	35.21
30	27.59	27.05	26.76	29.79	27.89	27.15	29.89	28.48	27.86	30.94	30.27	28.71	26.92	30.13	33.81	36.58
35	27.86	27.17	26.69	30.05	28.2	27.23	30.25	28.66	27.95	31.55	30.61	28.71	26.92	30.84	34.22	37.59
40	27.84	27.1	26.86	30.23	28.25	27.25	30.55	28.89	28	32.06	30.89	28.91	26.98	31.17	34.86	38.61
45	27.86	27.17	26.79	30.59	28.25	27.51	30.86	29.05	28.05	32.35	31.27	29.1	26.89	31.79	35.28	39.59
50	28.02	27.1	26.81	30.69	28.38	27.4	31.04	29.02	28.05	32.71	31.38	29.15	26.91	32.09	35.42	40.37
55	27.94	27.1	26.81	30.99	28.33	27.4	31.23	29.38	28.38	33.14	31.74	29.15	27.08	32.66	35.96	41.06
60	28.08	27	26.91	30.89	28.27	27.59	31.5	29.42	28.27	33.2	31.96	29.74	27.05	32.89	36.29	41.62
65	28.02	27.15	26.76	31.17	28.51	27.49	31.79	29.33	28.25	33.67	32.09	29.79	27.05	33.2	36.63	42.21
70	28.1	27.23	26.92	31.35	28.49	27.56	31.69	29.5	28.45	33.76	32.09	29.69	27.08	33.42	36.78	42.6
75	28.13	27.1	26.95	31.48	28.51	27.49	32.04	29.66	28.38	34.16	32.35	29.96	27.08	33.74	37.11	43.29
80	28.13	27.2	26.81	31.42	28.79	27.49	31.94	29.61	28.45	34.19	32.55	29.81	26.92	34.09	37.14	43.56
85	28.23	27.35	26.81	31.66	28.81	27.49	32.09	29.86	28.71	34.58	32.71	29.96	26.92	34.4	37.49	44.11
90	28.1	27.15	26.79	31.69	28.74	27.59	32.25	29.74	28.48	34.58	32.63	29.86	26.91	34.38	37.39	44.29
95	28.25	27.3	26.86	31.69	28.89	27.79	32.35	29.94	28.61	34.76	32.86	29.96	27.23	34.63	37.78	44.61
100	28.23	27.15	27	31.71	28.81	27.54	32.33	29.86	28.61	34.63	33.01	30.23	26.95	34.79	37.75	44.85
105	28.2	27.27	26.84	31.74	28.79	27.61	32.35	29.99	28.56	34.91	33.04	30.4	26.92	35.01	37.72	45.14
110	28.23	27.25	26.86	32.01	28.71	27.69	32.42	30.01	28.59	35.01	33.2	30.35	27.23	35.24	37.92	45.44
115	28.27	27.4	26.81	31.81	28.99	27.64	32.64	29.91	28.74	35.16	33.14	30.25	26.98	35.38	38.03	45.7
120	28.27	27.3	27.15	32.11	28.86	27.79	32.71	30.05	28.71	35.33	33.35	30.45	27.33	35.58	38.2	45.92

Table A1.3: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w1	T_w2
125	28.4	27.33	26.98	32.09	28.84	27.61	32.64	30.08	28.81	35.19	33.2	30.27	27.25	35.7	38.1	45.95
130	28.35	27.42	27.02	32.13	28.99	27.69	32.79	30.05	28.61	35.33	33.45	30.25	27.1	35.65	38.1	46.05
135	28.38	27.4	27.05	32.01	29	27.74	32.71	30.15	28.76	35.42	33.22	30.5	27.08	35.84	38.17	45.9
140	28.49	27.33	26.84	32.13	28.89	27.81	32.69	30.17	28.76	35.38	33.35	30.52	27.1	35.8	38.25	46.21
145	28.4	27.27	27.13	32.04	28.99	27.86	32.64	30.23	28.76	35.33	33.3	30.66	27.3	36.06	38.2	46.08

Table A1.4: Experimental Data for Small Sphere, $d_p = 2.9$ cm.
Run # 4: Re = 299 $Q_w = 243.4\ W/m^2$ $T_{amb} = 27.5\ ^oC$.
Time in (minutes), Temperature in (^{o}C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w1	T_w2
0	26.98	27.02	26.92	27.02	27.08	26.98	27.23	27.02	27.3	27.64	27.49	27.15	26.81	27.74	27.64	28.33
5	26.98	26.69	26.49	27.3	26.79	26.74	27.2	27.15	27.15	27.84	27.69	27.25	26.51	27.94	29.23	30.17
10	27.08	26.54	26.39	27.86	27.08	26.69	28	27.46	27.2	28.71	28.38	27.25	26.33	28.27	30.96	32.28
15	27.05	26.25	26.3	28.69	27.15	26.51	28.64	27.76	27.37	29.86	29.15	27.71	25.86	28.86	32.55	34.04
20	27.33	26.39	26.2	29.33	27.61	26.92	29.5	28.15	27.42	30.84	29.84	27.91	25.76	29.45	33.96	35.8
25	27.4	26.38	25.98	29.91	27.84	26.81	30.1	28.48	27.74	31.89	30.66	28.48	25.92	30.2	35.09	37.9
30	27.64	26.46	26.23	30.59	28.13	26.95	30.64	28.91	27.69	32.71	31.3	28.89	25.84	30.79	36.31	39.4
35	27.79	26.64	26.2	31.01	28.42	26.92	31.2	29.33	27.91	33.67	31.94	29.1	25.86	31.48	37.59	40.94
40	27.86	26.69	26.08	31.58	28.54	26.92	31.84	29.51	28.05	34.19	32.47	29.23	25.86	32.15	38.33	42.41
45	28.25	26.69	26.08	32.09	28.84	27.17	32.28	29.76	28.33	35.09	33.01	29.35	25.95	32.69	39.2	43.65
50	28.38	26.66	26.33	32.5	29.15	27.25	32.89	29.99	28.42	35.58	33.38	29.86	26.02	33.65	39.69	44.78
55	28.64	26.92	26.17	32.86	29.08	27.23	33.22	30.38	28.42	36.36	33.99	29.96	26.23	33.84	40.7	46.05
60	28.71	26.95	26.3	33.2	29.4	27.3	33.67	30.5	28.69	36.92	34.55	30.3	26.1	34.6	41.14	46.97
65	28.84	27.08	26.39	33.53	29.66	27.27	33.99	30.74	28.81	37.41	34.76	30.52	26.05	35.19	41.78	47.87
70	28.99	26.98	26.61	33.76	29.91	27.42	34.5	30.86	28.89	37.92	35.11	30.94	26.44	35.7	42.46	48.78
75	28.99	27.13	26.33	33.91	29.86	27.46	34.47	31.1	28.91	38.33	35.35	31.12	26.51	36.31	42.75	49.55
80	29.13	27.23	26.46	34.55	30.01	27.61	34.94	31.3	29.02	38.74	35.84	31.06	26.39	36.53	43.39	50.28
85	29.2	27.23	26.54	34.42	29.99	27.42	35.09	31.27	28.96	38.91	35.78	31.33	26.35	36.92	43.29	50.47
90	29.27	27.3	26.61	34.65	30.17	27.54	35.25	31.58	29.13	39.42	36.09	31.45	26.76	37.14	43.83	51.36
95	29.5	27.3	26.74	34.91	30.42	27.74	35.58	31.71	29.25	39.66	36.55	31.76	26.54	37.78	44.36	51.8
100	29.5	27.37	26.74	35.04	30.35	27.74	35.75	31.79	29.2	39.86	36.67	31.91	26.54	38.2	44.21	52.19
105	29.54	27.54	26.74	35.24	30.38	27.79	35.99	31.81	29.27	40.35	36.78	31.79	26.69	38.22	44.7	52.96
110	29.66	27.56	26.74	35.24	30.59	27.81	36.06	32.13	29.54	40.5	37.05	31.89	26.54	38.86	44.92	53.14
115	29.69	27.59	26.79	35.42	30.76	27.79	36.09	32.01	29.61	40.86	37.36	32.15	26.46	39.08	45.1	53.6
120	29.81	27.56	26.89	35.55	30.74	27.91	36.53	32.17	29.64	41.06	37.26	32.2	26.69	39.53	45.39	53.96

Table A1.4: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w1	T_w2
125	29.66	27.64	26.86	35.67	30.81	27.98	36.47	32.3	29.42	41.19	37.61	32.74	26.76	39.66	45.54	54.3
130	29.79	27.76	26.84	35.7	31.04	27.86	36.63	32.22	29.69	41.44	37.72	32.3	26.69	39.84	45.7	54.56
135	29.99	27.66	26.92	35.8	30.94	27.98	36.6	32.28	29.69	41.53	37.78	32.58	26.84	40.33	45.7	54.79
140	29.81	27.76	27.02	36.16	30.99	28.1	36.78	32.6	29.69	41.75	38	32.45	26.89	40.21	46.05	55.26
145	30.04	27.79	26.89	35.86	31.1	28.02	37.03	32.42	29.79	41.85	37.83	32.81	26.79	40.65	45.88	55.56
150	30.01	27.81	26.92	36.04	31.08	28.15	36.88	32.63	29.74	41.85	38.13	32.76	27.02	40.67	46.21	55.75
155	30.08	27.91	27.08	36.09	31.04	28.17	37.19	32.63	29.86	42	38.2	32.74	26.76	41.01	46.36	56.01
160	30.01	27.95	27.05	36.21	31.17	28.1	37.09	32.64	29.99	42.26	38.36	32.81	27.08	41.19	46.41	56.16
165	30.3	27.95	27.02	36.26	31.33	28.2	37.24	32.79	30.08	42.31	38.64	33.06	27.08	41.53	46.7	56.45
170	30.2	27.98	27.05	36.31	31.3	28.2	37.31	32.89	29.99	42.51	38.59	33.14	26.92	41.47	46.66	56.6
175	30.17	27.89	27.13	36.6	31.42	28.27	37.44	33.06	30.1	42.72	38.76	32.94	26.89	41.65	46.9	56.79
180	30.2	28	27.1	36.41	31.35	28.3	37.61	32.94	30.15	42.8	38.71	33.2	27.05	41.8	46.85	57.11
185	30.42	28.23	27.23	36.8	31.4	28.38	37.64	33.16	30.27	42.8	39	33.01	27.25	41.72	47.15	57.17
190	30.27	28.08	27.13	36.85	31.52	28.38	37.59	33.06	30.23	42.92	38.94	33.25	26.91	41.92	47.1	57.3
195	30.38	28.15	27.23	36.55	31.48	28.38	37.75	32.96	30.25	42.97	38.97	33.55	27.05	42.31	47.1	57.3
200	30.33	28.05	27.23	36.8	31.58	28.42	37.66	33.22	30.3	43.11	39.03	33.38	27.13	42.11	47.13	57.51
205	30.45	28.15	27.05	36.83	31.58	28.35	37.75	33.14	30.4	43.21	39.13	33.55	27.23	42.6	47.17	57.64
210	30.4	28.2	27.33	36.65	31.61	28.4	37.8	33.22	30.27	43.39	39	33.42	26.92	42.44	47.29	57.92
215	30.59	28.15	27.25	36.92	31.69	28.49	37.97	33.42	30.4	43.06	39.33	33.5	27.2	42.75	47.56	57.86
220	30.52	28.13	27.17	36.7	31.66	28.42	38	33.38	30.4	43.11	39.25	33.55	26.89	42.85	47.49	58.03
225	30.55	28.1	27.25	36.92	31.74	28.54	37.92	33.33	30.42	43.36	39.33	33.35	27.2	42.65	47.69	58.12

Table A1.5: Experimental Data for Small Sphere, $d_p = 2.9$ cm.
Run # 5: Re = 935.4 $Q_w = 179.2\ W/m^2$ $T_{amb} = 26.5\ ^oC$.
Time in (minutes), Temperature in (^oC) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w1	T_w2
0	24.66	24.56	24.79	24.83	24.79	24.92	25.27	25.17	25.46	25.41	25.41	25.56	24.79	25.76	25.41	25.81
5	24.85	24.71	24.71	25	24.9	24.95	25.15	25.1	25.25	25.59	25.54	25.49	24.81	25.74	25.88	26.64
10	24.85	24.66	24.71	25.35	24.85	24.95	25.49	25.3	25.46	26.02	25.98	25.66	24.87	26.27	26.66	27.61
15	25.15	25.1	24.81	25.71	25.05	25.15	25.56	25.46	25.46	26.38	26.17	25.81	25.17	26.56	27.15	28.51
20	25.41	25.13	25.02	26	25.46	25.36	26.05	25.71	25.59	26.81	26.38	26.02	25.35	26.81	27.61	29.38
25	25.66	25.41	25.08	26.3	25.76	25.27	26.35	25.71	25.76	27.05	26.66	25.95	25.46	27.15	28.05	30.17
30	25.66	25.56	25.36	26.51	25.71	25.46	26.61	26.12	26	27.42	26.98	26.1	25.9	27.42	28.54	30.81
35	25.9	25.61	25.36	26.64	25.76	25.56	26.89	26.2	25.98	27.71	27.2	26.33	25.74	27.86	28.81	31.52
40	26.02	25.69	25.49	26.71	25.98	25.64	26.91	26.38	25.98	28.05	27.46	26.38	25.79	28.1	29.05	31.86
45	26.15	25.71	25.61	27.05	26.15	25.86	27.15	26.54	26.2	28.33	27.64	26.92	26.05	28.27	29.5	32.3
50	26.1	25.9	25.61	27.13	26.3	25.9	27.44	26.64	26.33	28.51	27.86	26.76	25.98	28.56	29.61	32.74
55	26.39	25.9	25.81	27.13	26.35	26	27.4	26.64	26.25	28.45	27.94	26.95	26	28.84	29.79	33.09
60	26.38	26.02	25.69	27.23	26.38	26.08	27.46	26.71	26.35	28.69	27.94	27.02	26.1	28.84	29.99	33.38
65	26.35	25.9	25.81	27.35	26.35	26	27.69	26.95	26.41	28.76	28.1	27.23	26.02	29.1	30.08	33.76
70	26.46	26.12	25.74	27.35	26.46	26.08	27.66	27	26.39	29.13	28.23	27.17	26	29.02	30.08	33.89
75	26.49	25.88	25.84	27.46	26.41	26.02	27.66	26.89	26.44	29.02	28.27	27.08	26.25	29.42	30.27	34.16
80	26.51	25.95	25.66	27.44	26.46	26	27.79	27	26.54	29	28.33	27.33	26.15	29.48	30.33	34.14
85	26.59	26.08	25.79	27.51	26.46	26.12	27.95	27.17	26.64	29.23	28.38	27.44	26.3	29.51	30.45	34.25
90	26.49	26.2	25.86	27.54	26.64	26.2	28.02	27.02	26.76	29.4	28.45	27.25	26.15	29.69	30.45	34.47
95	26.69	26.15	25.9	27.74	26.64	26.25	27.89	27.1	26.61	29.25	28.54	27.49	26.17	29.71	30.42	34.7
100	26.69	26.25	26.05	27.84	26.74	26.25	28.02	27.2	26.81	29.35	28.69	27.44	26.27	29.96	30.76	34.84
105	26.71	26.23	25.98	27.69	26.76	26.27	28	27.15	26.86	29.5	28.69	27.56	26.46	29.96	30.76	35.01
110	26.69	26.27	26.17	27.71	26.84	26.38	28.17	27.23	26.84	29.48	28.66	27.51	26.49	30.05	30.89	34.91
115	26.69	26.25	26	27.84	26.84	26.44	28.17	27.2	26.95	29.66	28.81	27.81	26.33	30.05	30.81	35.11
120	26.74	26.39	26.2	27.86	26.79	26.39	28.42	27.27	26.91	29.69	28.84	27.69	26.59	30.04	30.69	35.09

Table A1.5: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w1	T_w2
125	26.81	26.33	26.12	27.86	26.86	26.56	28.3	27.3	26.89	29.71	28.91	27.51	26.25	30.17	30.89	35.28
130	26.84	26.44	26.15	27.91	26.84	26.39	28.23	27.37	26.95	29.86	29.1	27.71	26.46	30.25	30.81	35.42
135	26.74	26.39	26.15	27.95	26.84	26.54	28.23	27.23	27.02	29.66	28.99	27.74	26.39	30.27	30.94	35.28
140	26.86	26.27	26.23	28	26.95	26.46	28.45	27.56	27	29.81	28.91	27.61	26.56	30.3	30.81	35.55
145	26.91	26.46	26.27	28	27.05	26.61	28.4	27.46	27.05	29.91	29	27.91	26.61	30.35	30.81	35.53
150	26.92	26.54	26.3	27.98	26.98	26.49	28.38	27.54	26.98	29.89	29.02	27.74	26.49	30.33	30.94	35.63
155	26.79	26.35	26.1	27.94	26.92	26.49	28.51	27.44	27	29.94	28.99	27.79	26.3	30.55	30.84	35.67
160	26.49	26.15	25.9	27.66	26.69	26.25	28.17	27.33	26.86	29.59	28.79	27.84	26.35	30.4	30.74	35.4
165	26.54	26.1	25.9	27.89	26.59	26.44	28.3	27.25	26.98	29.71	28.76	27.56	26.17	30.42	30.81	35.55

Table A1.6: Experimental Data for Small Sphere, $d_p = 2.9$ cm.
Run # 6: Re = 756 $Q_w = 179.2\ W/m^2$ $T_{amb} = 26.5\ ^oC$.
Time in (minutes), Temperature in (^oC) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	25.49	25.39	25.49	25.54	25.59	25.69	25.79	25.74	26.08	26.17	26.08	26.17	25.49	26.44	26.08	26.49
5	25.79	25.59	25.59	25.98	25.84	25.79	26.02	26.02	26.08	26.38	26.27	26.33	26.12	26.51	26.98	27.51
10	26.1	25.9	25.66	26.39	26	25.86	26.54	26.25	26.38	27.05	27.05	26.46	26.23	27.05	28	28.71
15	26.33	26.08	25.84	26.86	26.23	26.23	27	26.51	26.41	27.51	27.37	26.76	26.56	27.33	28.71	29.84
20	26.59	26.25	26.15	27.4	26.39	26.44	27.44	26.92	26.69	28.15	27.64	27.05	26.59	27.84	29.45	30.89
25	26.66	26.33	26.17	27.51	26.71	26.38	27.71	27.08	26.69	28.45	28.02	27.35	26.59	28.25	29.86	31.79
30	26.74	26.54	26.25	27.84	26.84	26.59	28.13	27.2	26.95	28.86	28.4	27.59	26.51	28.54	30.27	32.6
35	26.91	26.61	26.23	27.95	26.86	26.61	28.25	27.3	26.95	29.45	28.59	27.54	26.61	28.96	30.56	33.25
40	26.86	26.61	26.33	28.15	26.81	26.71	28.35	27.4	27.02	29.42	28.86	27.61	26.84	29.17	30.79	33.84
45	26.89	26.64	26.54	28.17	27.08	26.64	28.51	27.69	27.13	29.56	28.91	27.86	26.84	29.51	31.15	34.25
50	27.02	26.49	26.44	28.27	27.02	26.69	28.64	27.54	27.2	30.01	29.15	28.15	26.56	29.64	31.33	34.65
55	27.13	26.59	26.3	28.38	27.08	26.59	28.66	27.56	27.25	30.01	29.1	27.91	26.81	29.96	31.35	34.99
60	27.13	26.64	26.59	28.42	27.23	26.69	28.81	27.71	27.17	30.27	29.33	28.08	26.98	30.23	31.71	35.47
65	26.98	26.69	26.39	28.56	27.27	26.84	29	27.81	27.23	30.27	29.48	28.05	26.76	30.48	31.76	35.78
70	27.08	26.79	26.49	28.56	27.33	26.79	28.86	27.86	27.3	30.42	29.56	28.05	26.56	30.48	31.91	36.04
75	27.2	26.71	26.38	28.59	27.35	26.76	28.84	27.84	27.25	30.48	29.4	28.15	26.51	30.56	31.84	36.09
80	27.17	26.64	26.44	28.66	27.23	26.84	29.1	27.86	27.37	30.52	29.66	28.48	26.64	30.74	31.91	36.53
85	27.02	26.71	26.46	28.76	27.37	26.76	29.15	27.95	27.37	30.64	29.74	28.27	26.79	30.74	31.91	36.53
90	27.17	26.69	26.44	28.91	27.33	26.89	29.15	28	27.33	30.84	29.71	28.2	26.79	31.04	32.2	36.9
95	27.13	26.84	26.49	28.91	27.33	26.92	29.1	28.1	27.44	30.76	29.74	28.33	26.91	30.96	32.13	36.92
100	27.3	26.76	26.38	28.74	27.3	26.81	29.27	27.98	27.42	30.94	29.86	28.45	26.76	31.12	32.4	36.95
105	27.25	26.66	26.51	28.79	27.44	26.86	29.27	28.13	27.54	31.01	29.89	28.59	26.66	31.25	32.22	37.03
110	27.3	26.61	26.66	28.79	27.3	26.86	29.25	28.15	27.49	30.91	29.86	28.59	26.91	31.23	32.3	37.14
115	27.2	26.59	26.54	28.76	27.4	26.92	29.38	28.13	27.51	30.89	30.01	28.61	26.89	31.33	32.37	37.31
120	27.17	26.69	26.49	29.02	27.4	26.79	29.13	28.08	27.44	31.08	29.91	28.49	26.86	31.33	32.45	37.24

Table A1.6: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	27.35	26.81	26.61	28.89	27.59	26.86	29.33	28.08	27.56	31.12	29.96	28.45	26.81	31.38	32.35	37.36
130	27.33	26.79	26.59	29	27.51	26.98	29.4	28.05	27.54	31.15	30.04	28.42	26.91	31.52	32.28	37.49
135	27.3	26.86	26.61	28.99	27.54	26.95	29.42	28.13	27.59	31.2	29.89	28.74	26.86	31.48	32.5	37.66
140	27.33	26.89	26.74	29.05	27.61	26.98	29.45	28.25	27.56	31.17	30.08	28.66	27.02	31.55	32.47	37.64
145	27.4	26.91	26.61	28.99	27.64	27	29.51	28.13	27.74	31.1	30.13	28.48	26.71	31.71	32.47	37.59
150	27.35	26.76	26.71	29.02	27.74	27.05	29.51	28.08	27.59	31.4	30.13	28.56	27.02	31.6	32.58	37.72
155	27.25	26.81	26.51	29.02	27.44	26.81	29.38	28.1	27.56	31.2	30.25	28.49	26.56	31.61	32.45	37.83
160	27.15	26.66	26.41	29.02	27.4	27	29.4	28.15	27.51	31.17	30.1	28.56	26.69	31.74	32.58	37.95

Table A1.7: Experimental Data for Small Sphere, $d_p = 2.9$ cm.
Run # 7: Re = 538.2 $Q_w = 179.2\ W/m^2$ $T_{amb} = 26.5\ ^oC$.
Time in (minutes), Temperature in (^oC) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	25.66	25.61	25.46	25.9	25.81	25.9	25.86	26.05	26.46	26.41	26.38	26.27	25.49	26.56	26.41	26.41
5	25.79	25.84	25.64	26.12	25.84	25.88	25.98	26.12	26.25	26.56	26.46	26.51	26	26.76	27.2	27.74
10	26.1	25.95	25.76	26.64	26.15	26.05	26.59	26.25	26.41	26.95	26.95	26.81	26.17	26.95	28.23	28.96
15	26.38	26.02	26.08	27.2	26.27	26.27	27.1	26.71	26.61	27.79	27.64	26.95	26.15	27.49	29.25	30.23
20	26.59	26.2	26	27.64	26.64	26.2	27.59	27.1	26.61	28.42	28.1	27.27	26.66	27.76	30.13	31.45
25	26.81	26.51	26.17	28.1	26.91	26.33	28.05	27.13	26.81	29	28.35	27.42	26.41	28.4	30.84	32.55
30	27.02	26.38	26.12	28.51	26.86	26.46	28.48	27.46	26.95	29.51	28.81	27.71	26.46	28.81	31.3	33.58
35	27.1	26.56	26.38	28.69	27.2	26.61	28.94	27.59	27.2	29.96	29.25	27.89	26.41	29.2	32.01	34.5
40	27.13	26.54	26.39	29.02	27.17	26.59	29.13	27.89	27.23	30.4	29.54	27.94	26.74	29.74	32.45	35.28
45	27.27	26.59	26.39	29.23	27.37	26.74	29.51	27.94	27.51	30.69	29.86	28.2	26.84	30.04	32.94	36.16
50	27.35	26.71	26.41	29.48	27.49	26.76	29.64	28.13	27.23	31.01	30.17	28.23	26.59	30.4	33.06	36.75
55	27.4	26.64	26.35	29.56	27.49	26.84	29.94	28.17	27.56	31.4	30.1	28.35	26.98	30.89	33.6	37.31
60	27.44	26.74	26.39	29.71	27.64	26.84	30.08	28.33	27.44	31.58	30.45	28.59	26.95	31.01	33.79	37.83
65	27.42	26.84	26.69	29.91	27.71	26.92	30.27	28.42	27.79	31.89	30.5	28.59	26.95	31.33	34.11	38.41
70	27.42	26.84	26.54	29.96	27.66	26.98	30.45	28.49	27.84	31.89	30.86	28.64	26.66	31.38	34.16	38.64
75	27.51	26.84	26.54	30.15	27.76	27.02	30.48	28.66	27.66	32.25	31.04	29.1	26.79	31.64	34.45	39.05
80	27.69	26.86	26.56	30.13	27.84	27	30.52	28.61	27.81	32.3	31.06	29.05	26.95	31.89	34.42	39.3
85	27.61	26.98	26.64	30.3	27.81	27.02	30.64	28.79	27.81	32.35	31.33	29.1	26.69	32.09	34.7	39.58
90	27.61	26.89	26.69	30.3	28.05	26.89	30.64	28.84	27.86	32.5	31.15	29.1	26.86	32.35	34.89	39.94
95	27.56	26.89	26.59	30.4	27.95	27.08	30.86	28.71	27.84	32.58	31.3	29.38	26.76	32.53	34.81	40.25
100	27.84	26.98	26.59	30.4	27.98	27.02	30.86	28.91	27.98	32.76	31.5	29.33	26.89	32.58	34.96	40.33
105	27.71	26.92	26.64	30.4	28	27.02	30.94	29	28.05	32.91	31.58	29.2	26.79	32.76	35.04	40.6
110	27.71	27.02	26.64	30.5	27.95	27.23	30.86	29	27.95	32.91	31.52	29.3	27.02	32.96	35.21	40.7
115	27.69	26.95	26.66	30.61	28.08	27.15	30.99	29.02	28.02	33.04	31.69	29.48	27	33.04	35.01	41.11
120	27.84	27	26.71	30.56	27.98	27.2	31.12	29.02	27.98	33.09	31.69	29.51	26.84	33.14	35.21	41.04

Table A1.7: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	27.71	27.02	26.74	30.5	28.05	27.17	31.06	29	28.05	33.11	31.66	29.45	26.89	33.2	35.45	41.06
130	27.74	27	26.74	30.61	28.2	27.3	31.04	29.08	28.13	32.99	31.64	29.51	26.86	33.45	35.33	41.21
135	27.79	27.05	26.71	30.71	28.23	27.35	31.15	29.08	27.95	33.35	31.81	29.35	26.86	33.2	35.28	41.34
140	27.76	27.23	26.69	30.69	28.1	27.13	31.17	29.08	28.02	33.17	31.74	29.51	26.84	33.42	35.35	41.36
145	27.91	27.23	26.74	30.79	28.1	27.27	31.27	29.17	28.17	33.28	31.74	29.51	27.13	33.58	35.45	41.67
150	27.84	27.1	26.81	30.81	28.17	27.3	31.15	29.2	28.15	33.5	31.91	29.5	27.08	33.58	35.42	41.55
155	27.76	27.02	26.66	30.79	28.25	27.37	31.35	29.1	28.23	33.45	31.79	29.48	26.95	33.69	35.58	41.78
160	27.91	27.17	26.74	30.89	28.2	27.37	31.42	29.13	28.13	33.53	31.94	29.66	27.02	33.79	35.55	41.97
165	27.91	27.17	26.69	30.84	28.25	27.33	31.4	29.25	28.27	33.67	32.13	29.76	26.98	33.67	35.65	41.78
170	27.91	27.08	26.84	30.84	28.25	27.33	31.4	29.13	28.13	33.62	32.28	29.66	26.92	33.94	35.72	42.09
175	27.94	27.1	26.86	31.01	28.38	27.64	31.45	29.25	28.17	33.58	32.2	29.71	27	34.04	35.86	42.26
180	27.95	27.27	26.89	30.99	28.3	27.42	31.48	29.38	28.2	33.5	32.13	29.69	27.08	34.09	35.8	42.24
185	27.94	27.2	26.86	30.96	28.23	27.4	31.48	29.33	28.25	33.6	32.06	29.59	26.95	33.86	35.8	42.21
190	27.94	27.2	26.86	31.1	28.17	27.25	31.5	29.35	28.42	33.69	32.13	29.76	27.25	34.25	36.09	42.41
195	27.98	27.2	26.91	31.06	28.38	27.35	31.48	29.23	28.4	33.69	32.15	29.61	27	34.25	35.89	42.44

Table A1.8: Experimental Data for Small Sphere, $d_p = 2.9$ cm.
Run # 8: Re = 299 $Q_w = 179.2$ W/m^2 $T_{amb} = 26.5$ °C.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	25.54	25.69	25.59	25.79	25.69	25.88	25.92	25.88	26.23	26.23	26.27	26.17	25.49	26.61	26.23	26.38
5	25.69	25.59	25.54	25.98	25.64	25.69	25.84	25.84	26.25	26.44	26.49	26.3	25.74	26.59	27.17	27.46
10	26.15	25.71	25.61	26.54	26.05	26.05	26.64	26.2	26.35	27.05	26.81	26.25	25.76	26.81	28.64	29.1
15	26.30	25.66	25.61	27.27	26.15	25.95	26.98	26.44	26.49	27.84	27.54	26.54	25.86	27.17	29.86	30.48
20	26.51	25.84	25.74	27.76	26.51	25.98	27.69	26.95	26.69	28.42	28.17	27.02	25.69	27.56	30.91	32.01
25	26.79	25.9	25.66	28.23	26.92	26	28.27	27.15	26.69	29.4	28.64	27.49	25.76	28.08	32.06	33.47
30	26.64	25.9	25.86	28.76	26.98	26.15	28.86	27.46	26.84	30.05	29.3	27.59	25.71	28.64	32.99	34.63
35	26.98	26.1	25.81	29.15	27.27	26.2	29.23	27.86	26.92	30.86	29.74	27.84	25.81	29.17	33.81	35.89
40	27.15	26.02	25.59	29.54	27.4	26.33	29.79	28.15	26.95	31.3	30.27	28	25.86	29.71	34.63	37.05
45	27.18	26.1	25.71	29.94	27.54	26.35	30.17	28.27	27.15	31.96	30.69	28.3	25.74	30.27	35.21	38.17
50	27.35	26.17	25.79	30.33	27.89	26.41	30.59	28.79	27.27	32.66	31.1	28.59	25.76	30.66	35.99	39.08
55	27.30	26.17	25.84	30.27	27.89	26.41	30.59	28.59	27.37	32.66	31.1	28.51	26	30.81	35.99	39.47
60	27.43	26.39	25.71	30.71	27.94	26.3	31.12	28.76	27.4	33.25	31.6	28.66	25.92	31.3	36.6	40.16
65	27.59	26.17	25.79	31.04	28.15	26.56	31.35	28.89	27.54	33.55	31.79	28.99	26.05	31.74	37.21	41.01
70	27.66	26.49	26.05	31.25	28.2	26.59	31.61	29.25	27.59	33.91	32.2	28.89	25.86	32.06	37.39	41.9
75	27.91	26.44	25.9	31.55	28.35	26.69	31.71	29.4	27.69	34.42	32.5	29.27	26	32.55	38.03	42.49
80	27.74	26.46	25.9	31.55	28.54	26.51	32.15	29.48	27.64	34.72	32.81	29.13	25.86	32.81	38.36	43.06
85	28.00	26.49	25.95	31.81	28.54	26.79	32.28	29.54	27.86	35.11	32.86	29.56	25.84	33.33	38.49	43.7
90	28.10	26.54	25.9	31.91	28.64	26.84	32.47	29.64	27.94	35.45	33.09	29.64	26.2	33.69	39.17	44.29
95	28.15	26.44	25.92	32.11	28.66	26.74	32.79	29.79	27.86	35.7	33.42	29.79	25.95	34.06	39.1	44.67
100	28.08	26.56	25.92	32.42	28.76	26.91	32.79	29.91	28.05	35.99	33.4	29.81	26.08	34.22	39.4	45.1
105	28.25	26.59	26.1	32.45	28.89	26.79	33.06	29.94	28.08	35.8	33.79	30.04	25.86	34.6	39.71	45.66
110	28.33	26.46	25.98	32.28	28.86	26.81	33.11	30.05	28.1	36.31	33.91	30.15	26.08	34.86	39.84	45.95
115	28.33	26.66	26.08	32.74	28.99	26.81	33.25	30.1	28.25	36.63	34.04	30.17	25.98	35.21	40.19	46.39
120	28.23	26.66	26.05	32.69	28.99	26.95	33.4	30.25	28.25	36.44	34.25	30.17	26.17	35.53	40.28	46.61

Table A1.8: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	28.48	26.76	25.88	32.76	29.05	27.05	33.33	30.2	28.23	36.88	34.3	30.35	26	35.38	40.47	47.03
130	28.33	26.66	26.02	32.86	29.1	26.81	33.69	30.25	28.35	36.88	34.33	30.45	25.86	35.91	40.37	47.17
135	28.35	26.74	26.1	32.84	29.23	26.89	33.58	30.27	28.35	37.09	34.6	30.55	26.05	36.06	40.6	47.51
140	28.45	26.74	26.05	33.11	29.23	26.92	33.76	30.38	28.35	37.11	34.65	30.38	26.23	36.31	40.94	47.69
145	28.35	26.69	26.08	33.06	29.1	26.92	33.71	30.5	28.42	37.44	34.72	30.64	26.17	36.44	40.8	47.75
150	28.43	26.71	26.1	33.17	29.23	27	33.81	30.52	28.42	37.66	34.67	30.56	26.17	36.47	40.89	48
155	28.30	26.64	26.2	33.2	29.23	26.92	34.01	30.52	28.56	37.39	34.79	30.69	25.95	36.8	40.91	48.24
160	28.43	26.76	26.1	33.22	29.3	27.05	33.96	30.64	28.45	37.69	34.86	30.81	26.02	36.78	41.09	48.31
165	28.56	26.71	26.15	33.22	29.3	27.05	34.01	30.55	28.48	37.66	34.94	30.79	26.2	37.11	41.19	48.7
170	28.43	26.79	26.1	33.17	29.38	26.95	34.01	30.52	28.61	37.75	34.96	30.89	26.08	37.39	41.16	48.75
175	28.38	26.79	26.05	33.17	29.23	27.2	33.96	30.71	28.49	37.88	34.96	30.84	26.17	37.21	41.11	48.67
180	28.59	26.74	26.2	33.3	29.42	27.13	33.96	30.61	28.61	37.88	34.99	31.04	26.2	37.39	41.34	48.92
185	28.54	26.84	26.17	33.2	29.38	27.13	34.19	30.66	28.4	37.97	35.19	30.94	25.98	37.54	41.34	49.01
190	28.45	26.74	26.23	33.25	29.38	27.08	34.22	30.66	28.61	37.92	35.3	30.69	26.05	37.7	41.5	48.99
195	28.54	26.86	25.98	33.53	29.45	27.1	34.28	30.69	28.64	38.17	35.33	31.01	25.92	37.69	41.53	49.42
200	28.54	26.61	26.12	33.3	29.4	27.08	34.19	30.74	28.54	38.17	35.38	31.27	26.33	37.9	41.47	49.14
205	28.38	26.84	26.05	33.45	29.48	27.13	34.11	30.81	28.64	38.28	35.25	30.81	25.95	37.83	41.58	49.47
210	28.48	26.81	26.15	33.42	29.38	27.15	34.3	30.81	28.66	38.3	35.45	31.23	26.08	38.13	41.6	49.42
215	28.54	26.84	26.12	33.5	29.4	27.02	34.22	30.71	28.64	38.3	35.42	31.12	25.88	38.03	41.44	49.72
220	28.51	26.76	26.25	33.58	29.64	27.1	34.3	30.84	28.69	38.34	35.65	31.06	26.02	38.05	41.7	49.72
225	28.54	26.79	26.17	33.4	29.48	27.02	34.38	30.86	28.71	38.49	35.4	31.15	26.05	38.28	41.78	49.75
230	28.64	26.74	26.12	33.5	29.51	27.13	34.28	30.81	28.71	38.51	35.6	31.04	26.12	38.2	41.78	49.86
235	28.48	26.81	26.08	33.47	29.5	27.05	34.6	30.69	28.69	38.59	35.75	31.42	26.05	38.49	41.85	50.01
240	28.45	26.64	26.15	33.45	29.56	27.08	34.42	30.96	28.56	38.54	35.38	31.15	25.95	38.44	41.78	49.94
245	28.51	26.76	26.05	33.53	29.45	27.05	34.45	31.04	28.71	38.49	35.63	31.1	26.05	38.54	41.83	50.01
250	28.38	26.79	26.1	33.47	29.48	26.98	34.4	30.76	28.61	38.51	35.67	31.33	25.92	38.59	41.78	49.94

Table A1.9: Experimental Data for Small Sphere, $d_p = 2.9$ cm.
Run # 9: Re = 935.4 $Q_w = 79.4$ W/m^2 $T_{amb} = 26.5$ °C.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	24.25	24.49	24.49	24.3	24.44	24.54	24.44	24.54	25	25	24.81	24.95	24.66	25.15	24.61	25.05
5	24.74	24.64	24.74	24.69	24.74	24.79	24.87	24.64	25.02	25.08	25.02	24.92	24.98	25.17	25.23	25.64
10	24.9	25	24.76	25.05	24.9	24.85	24.95	25.1	25.15	25.25	25.39	25.15	25.1	25.39	25.69	26.17
15	25.33	25.08	24.87	25.23	25.08	25.02	25.33	25.08	25.33	25.71	25.56	25.27	25.51	25.56	25.95	26.54
20	25.35	25.15	24.95	25.49	25.25	25.15	25.54	25.39	25.39	25.84	25.79	25.35	25.49	25.79	26.39	27.02
25	25.41	25.23	25.02	25.56	25.41	25.27	25.81	25.41	25.41	26.17	26.02	25.46	25.36	26.08	26.56	27.33
30	25.39	25.44	25.15	25.64	25.44	25.2	25.84	25.69	25.54	26.23	26.08	25.39	25.39	26.17	26.76	27.76
35	25.49	25.56	25.3	25.9	25.49	25.35	25.9	25.66	25.74	26.35	26.15	25.88	25.69	26.3	26.89	27.94
40	25.56	25.33	25.23	25.95	25.56	25.46	25.95	25.81	25.69	26.46	26.23	25.88	25.44	26.41	27.08	28.13
45	25.51	25.33	25.23	25.81	25.56	25.38	25.9	25.66	25.76	26.64	26.44	25.81	25.51	26.49	27	28.45
50	25.71	25.46	25.36	26	25.56	25.51	26.05	25.66	25.79	26.69	26.41	26.02	25.74	26.74	26.98	28.48
55	25.64	25.54	25.54	25.98	25.69	25.44	26.12	25.88	25.81	26.81	26.51	26	25.66	26.86	27.3	28.61
60	25.64	25.51	25.36	26.17	25.69	25.36	26.17	25.79	25.71	26.81	26.56	26.1	25.61	26.86	27.3	28.71
65	25.69	25.59	25.49	26.02	25.59	25.59	26.25	25.92	25.92	26.95	26.51	26.02	25.79	26.86	27.4	28.86
70	25.92	25.59	25.69	26.17	25.79	25.54	26.17	25.84	25.9	26.91	26.56	26.1	25.9	26.95	27.35	28.91
75	25.95	25.66	25.61	26.3	25.95	25.71	26.39	26	25.95	27.17	26.79	26.1	25.95	27.08	27.51	29.35
80	25.95	25.76	25.61	26.35	25.9	25.71	26.46	26.15	25.95	27	26.64	26.3	25.95	27.1	27.74	29.25
85	25.86	25.71	25.71	26.39	25.86	25.71	26.44	26	25.98	27.23	26.79	26.39	25.92	27.17	27.61	29.17
90	26.08	25.86	25.71	26.27	25.95	25.76	26.56	26.12	26	27.08	26.84	26.15	26.2	27.23	27.54	29.35
95	25.95	25.9	25.76	26.35	26.15	25.81	26.54	26.2	26.08	27.27	26.76	26.23	26.08	27.42	27.76	29.42
100	25.92	25.88	25.66	26.41	25.92	25.88	26.41	26.12	25.95	27.23	26.92	26.35	25.95	27.27	27.64	29.5
105	26.05	25.79	25.74	26.39	25.92	25.69	26.54	26.25	26.08	27.35	26.81	26.61	26.08	27.35	27.71	29.48
110	26.05	25.86	25.69	26.44	26	25.81	26.69	26.25	26.15	27.37	26.89	26.54	25.95	27.46	27.79	29.59
115	25.88	25.79	25.59	26.27	25.92	25.74	26.64	26.23	26.1	27.25	26.91	26.41	25.95	27.4	27.89	29.66
120	25.98	25.88	25.79	26.49	25.92	25.79	26.64	26.17	26.15	27.25	27.05	26.39	25.9	27.54	27.69	29.5

Table A1.9: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	26.17	25.84	25.74	26.51	26.23	25.79	26.66	26.33	26.15	27.42	26.98	26.49	26.1	27.56	27.94	29.64
130	26.02	25.74	25.69	26.41	26.08	25.84	26.56	26.33	26.15	27.27	26.98	26.59	26.05	27.51	27.89	29.79
135	26.08	25.84	25.79	26.46	25.98	25.84	26.66	26.33	26.15	27.37	27.02	26.39	26.15	27.56	27.89	29.59
140	26.23	25.88	25.74	26.61	26.17	25.98	26.61	26.41	26.25	27.33	27.08	26.49	26.25	27.42	27.94	29.69
145	25.95	26	25.66	26.51	26.2	25.95	26.66	26.41	26.15	27.51	26.98	26.54	26	27.56	27.98	29.79
150	26.2	25.95	25.9	26.54	26.1	25.81	26.76	26.44	26.15	27.59	27.08	26.54	26.05	27.74	27.89	29.74
155	26.08	25.92	25.88	26.56	26.12	25.98	26.76	26.41	26.25	27.54	27.1	26.54	26.1	27.59	27.84	29.79
160	26.1	25.95	25.76	26.69	26.15	25.95	26.69	26.35	26.25	27.46	27.08	26.64	26.05	27.64	27.84	29.99
165	26.17	26.08	25.98	26.56	26.27	26.02	26.66	26.41	26.25	27.46	27.08	26.74	26.08	27.56	27.89	30.04
170	26.17	26.02	25.74	26.61	26.12	26.02	26.76	26.46	26.3	27.64	27.15	26.59	26.15	27.64	27.89	29.96
175	26.3	26.05	25.86	26.54	26.1	26	26.71	26.44	26.38	27.46	27.17	26.84	26.17	27.66	27.95	29.84
180	26.25	25.9	25.9	26.49	26	25.86	26.74	26.39	26.3	27.46	27.08	26.54	26.2	27.69	28.08	29.89

Table A1.10: Experimental Data for Small Sphere, $d_p = 2.9$ cm.
Run # 10: Re = 756 $Q_w = 79.4\ W/m^2$ $T_{amb} = 25.0\ ^{\circ}C$.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	24.23	24.13	24.13	24.13	24.08	24.23	24.17	24.17	24.56	24.41	24.46	24.56	24.46	24.61	24.61	24.61
5	24.44	24.27	24.17	24.31	24.39	24.23	24.39	24.23	24.61	24.71	24.76	24.51	24.56	24.83	24.98	25.13
10	24.69	24.59	24.39	24.54	24.39	24.3	24.79	24.49	24.59	25.1	24.87	24.74	24.74	24.98	25.39	25.79
15	24.71	24.51	24.46	24.85	24.51	24.46	24.95	24.71	24.74	25.27	25.13	24.69	24.87	25.23	25.88	26.27
20	24.92	24.83	24.41	25.02	24.83	24.74	25.13	25.02	24.76	25.69	25.44	24.9	24.95	25.35	26.05	26.74
25	24.95	24.74	24.54	25.2	24.85	24.59	25.39	24.9	24.85	25.76	25.56	25.08	24.85	25.46	26.3	27.3
30	25.17	24.79	24.69	25.36	24.92	24.79	25.51	25.17	25.08	26.08	25.58	25.13	25.13	25.71	26.71	27.51
35	25.2	24.9	24.61	25.56	25	24.76	25.61	25.15	25.08	26.05	25.81	25.33	25.23	26	26.81	28
40	25.08	24.98	24.64	25.56	25.23	24.87	25.61	25.17	25.17	26.25	25.95	25.46	25.17	26.05	27.05	28.33
45	25.2	25.05	24.85	25.71	25.2	24.85	25.81	25.39	25.15	26.38	26.08	25.2	25.08	26.23	26.98	28.45
50	25.3	25.1	24.76	25.76	25.25	24.85	25.86	25.36	25.23	26.56	26.15	25.36	25.27	26.38	27.2	28.66
55	25.2	25	24.95	25.79	25.25	25.1	25.92	25.54	25.35	26.54	26.39	25.54	25.35	26.64	27.23	29.05
60	25.46	25.13	24.92	25.81	25.13	25.17	26	25.51	25.3	26.92	26.39	25.54	25.25	26.59	27.54	29.1
65	25.41	25.02	24.92	25.81	25.36	25.02	25.98	25.56	25.39	26.79	26.33	25.74	25.25	26.61	27.46	29.2
70	25.35	25.05	24.95	25.84	25.3	25.2	26.12	25.69	25.49	26.98	26.46	25.84	25.3	26.98	27.51	29.4
75	25.46	25.13	24.98	25.98	25.33	25.08	26.12	25.66	25.39	26.89	26.3	25.81	25.35	26.84	27.44	29.38
80	25.39	25.1	25	26.15	25.44	25.15	26.25	25.84	25.61	27.1	26.61	25.71	25.33	27	27.61	29.42
85	25.41	25.23	24.92	25.95	25.36	25.13	26.1	25.61	25.41	26.95	26.51	25.79	25.27	27	27.61	29.69
90	25.33	25.23	25.02	25.95	25.56	25.27	26.3	25.81	25.71	27.05	26.61	25.92	25.41	27.05	27.76	29.64
95	25.36	25.23	24.98	25.95	25.36	25.23	26.38	25.9	25.59	27.08	26.61	25.88	25.35	27.13	27.71	29.79
100	25.39	25.1	25.1	26.12	25.44	25.25	26.38	25.74	25.46	27.15	26.56	25.84	25.56	27.05	27.61	29.79
105	25.36	25.33	25.08	25.98	25.56	25.23	26.27	25.79	25.51	26.98	26.59	25.86	25.41	27.02	27.84	29.86
110	25.49	25.2	25.15	26.1	25.44	25.35	26.25	25.92	25.59	27.08	26.66	25.98	25.59	27.23	27.66	29.84
115	25.39	25.2	25.15	25.98	25.54	25.25	26.35	25.84	25.64	27.17	26.61	26.17	25.39	27.27	27.71	29.96
120	25.49	25.25	25.1	26.02	25.59	25.3	26.23	25.79	25.71	27.3	26.71	26.25	25.27	27.4	28	29.99

Table A1.10: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	25.46	25.1	25.1	26.1	25.56	25.33	26.44	25.95	25.69	27.17	26.71	26.12	25.35	27.42	27.81	30.15
130	25.51	25.17	24.98	26.05	25.36	25.33	26.25	25.86	25.69	27.13	26.66	26.02	25.39	27.27	27.71	29.99
135	25.56	25.25	25	26.15	25.51	25.2	26.49	25.86	25.51	27.05	26.74	26.1	25.33	27.25	27.74	30.08

Table A1.11: Experimental Data for Small Sphere, $d_p = 2.9$ cm.
Run # 11: Re = 538.2 $Q_w = 79.4$ W/m^2 $T_{amb} = 24.5$ °C.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	23.38	24.02	23.85	24.08	23.98	24.02	24.17	24.17	24.39	24.39	24.49	24.54	23.85	24.44	24.44	24.49
5	23.95	23.85	23.85	24	23.8	23.9	24.1	24.05	24.3	24.44	24.3	24.15	24	24.59	24.79	25.02
10	24.25	23.95	23.95	24.3	23.95	24	24.3	24.2	24.59	24.69	24.54	24.59	24.25	24.83	25.23	25.64
15	24.25	24	24	24.49	24.1	24.1	24.44	24.3	24.54	25.02	24.87	24.54	24.27	24.79	25.61	26.02
20	24.31	24.17	24.13	24.66	24.23	24.27	24.81	24.56	24.41	25.17	25.08	24.74	24.46	25.02	26.08	26.61
25	24.31	24.27	24.02	24.85	24.41	24.31	25	24.56	24.46	25.59	25.15	24.85	24.61	25.3	26.25	27.1
30	24.61	24.36	24.17	25.15	24.51	24.36	25.15	24.71	24.64	25.71	25.51	24.87	24.39	25.56	26.66	27.54
35	24.49	24.25	24.2	25.2	24.54	24.39	25.35	24.85	24.76	26.05	25.71	25.25	24.46	25.66	26.81	27.95
40	24.69	24.44	24.27	25.46	24.64	24.23	25.51	24.92	24.79	26.17	25.88	25.08	24.64	25.88	27.08	28.3
45	24.66	24.41	24.27	25.49	24.66	24.36	25.66	25.05	24.83	26.23	25.88	25.17	24.74	25.92	27.13	28.74
50	24.79	24.51	24.23	25.51	24.74	24.46	25.66	25.17	24.83	26.44	25.92	25.39	24.69	26.02	27.4	28.81
55	24.87	24.44	24.3	25.76	24.74	24.44	25.86	25.23	24.95	26.66	26.15	25.41	24.76	26.35	27.61	29.13
60	24.85	24.61	24.36	25.81	24.81	24.51	25.95	25.27	24.9	26.69	26.1	25.35	24.76	26.39	27.61	29.5
65	24.87	24.59	24.49	25.66	24.87	24.64	25.95	25.17	25.08	26.84	26.33	25.33	24.64	26.41	27.84	29.51
70	24.85	24.56	24.46	25.9	24.95	24.56	26.15	25.39	25	26.84	26.38	25.49	24.74	26.64	27.89	29.66
75	24.98	24.59	24.54	25.9	24.92	24.74	26.17	25.41	25.05	26.98	26.38	25.44	24.9	26.79	28.13	29.91
80	25.02	24.64	24.39	25.98	24.98	24.74	26.12	25.51	24.98	27.2	26.56	25.61	24.87	26.76	28.1	30.05
85	25.02	24.69	24.54	26.02	25.08	24.69	26.27	25.49	25.2	27.2	26.54	25.49	24.95	27	28.2	30.35
90	25.13	24.74	24.54	26.05	25.08	24.74	26.39	25.56	25.13	27.2	26.66	25.71	24.83	27.05	28.1	30.35
95	25.02	24.79	24.64	26.1	25.17	24.87	26.35	25.56	25.2	27.35	26.79	25.76	24.85	27.25	28.35	30.59
100	25.1	24.9	24.51	26.12	25.1	24.76	26.41	25.69	25.23	27.23	26.76	25.56	24.98	27.27	28.33	30.66
105	25.23	24.79	24.59	26.3	25.33	24.79	26.49	25.71	25.25	27.37	26.79	25.84	24.95	27.42	28.42	30.74
110	25.23	24.79	24.54	26.23	25.27	24.83	26.46	25.66	25.2	27.49	26.92	25.69	25.05	27.37	28.59	30.89
115	25.05	24.76	24.71	26.27	25.2	24.76	26.51	25.84	25.44	27.64	26.79	25.92	25	27.49	28.49	30.89
120	25	24.76	24.76	26.27	25.05	24.76	26.56	25.64	25.35	27.37	26.92	25.69	24.95	27.54	28.49	30.89

Table A1.11: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	25.27	24.87	24.64	26.35	25.23	24.92	26.61	25.76	25.35	27.59	27.02	25.79	24.95	27.49	28.54	31.15
130	25.17	24.87	24.83	26.38	25.33	25.02	26.66	25.81	25.35	27.66	27.08	26.02	25.05	27.66	28.64	31.12
135	25.3	24.85	24.66	26.35	25.35	24.85	26.64	25.69	25.46	27.49	27	26	24.98	27.54	28.59	31.2
140	25.27	24.98	24.74	26.39	25.33	25.02	26.74	25.95	25.39	27.79	27.17	26	25.1	27.79	28.74	31.2
145	25.27	24.87	24.64	26.44	25.33	24.98	26.76	25.9	25.33	27.76	27	26	24.87	27.76	28.61	31.2
150	25.35	24.95	24.76	26.41	25.39	25.05	26.74	25.92	25.46	27.76	27.15	25.95	25.13	27.81	28.71	31.48
155	25.23	24.92	24.74	26.27	25.27	25.08	26.76	25.88	25.44	27.71	27.17	25.92	24.95	27.89	28.74	31.35
160	25.27	24.87	24.69	26.61	25.36	24.98	26.71	25.9	25.49	27.66	27.17	25.92	25.05	27.94	28.84	31.27
165	25.27	25.02	24.79	26.51	25.27	25.02	26.86	25.88	25.54	27.66	27.13	26.17	25	27.94	28.84	31.55
170	25.15	24.85	24.66	26.51	25.39	25	26.86	25.92	25.54	27.79	27.23	26.02	24.95	27.84	28.79	31.45
175	25.3	25.05	24.81	26.46	25.35	25	26.71	25.98	25.66	27.85	27.1	26	24.92	27.86	28.86	31.48

Table A1.12: Experimental Data for Small Sphere, $d_p = 2.9$ cm.
Run # 12: Re = 299 $Q_w = 79.4$ W/m^2 $T_{amb} = 25.5$ °C.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	24.76	24.76	24.9	24.81	24.81	24.81	24.85	24.95	25.15	25.3	25.2	25.15	24.56	25.44	25.3	25.35
5	24.95	24.9	24.71	24.85	24.66	24.81	24.9	24.95	25.13	25.33	25.23	25.27	24.92	25.36	25.74	25.92
10	24.95	24.9	24.81	25.1	25.05	24.9	25.05	25.1	25.23	25.56	25.61	25.23	25.17	25.66	26.3	26.54
15	25.2	25	24.95	25.44	25.1	24.9	25.49	25.2	25.39	25.95	25.86	25.44	25.35	25.71	27	27.15
20	25.39	25.15	24.95	25.74	25.35	25	25.88	25.49	25.35	26.39	25.95	25.49	25.25	25.95	27.3	27.89
25	25.51	25.23	24.92	26.05	25.27	25.08	26.15	25.56	25.44	26.66	26.41	25.74	25.1	26.02	27.89	28.38
30	25.56	25.23	25.02	26.15	25.46	25.08	26.39	25.76	25.41	26.91	26.46	25.66	25.33	26.41	28.33	28.89
35	25.69	25.25	25	26.46	25.69	25.3	26.51	25.98	25.59	27.33	26.98	26.02	25.44	26.56	28.69	29.64
40	25.79	25.2	25.05	26.66	25.84	25.1	26.79	26.02	25.76	27.59	27.02	25.9	25.3	26.92	28.96	30.13
45	25.84	25.39	25.1	27.02	25.88	25.3	26.92	26.33	25.81	27.98	27.35	26.2	25.44	27.02	29.5	30.52
50	25.81	25.3	25.3	27	25.86	25.2	27.25	26.23	25.74	28.27	27.46	26.23	25.35	27.37	29.45	31.08
55	25.98	25.44	25.27	27.27	25.98	25.36	27.33	26.49	25.92	28.17	27.61	26.17	25.49	27.37	29.89	31.27
60	26	25.33	25.08	27.2	26.05	25.41	27.49	26.49	25.86	28.54	27.69	26.44	25.51	27.49	30.17	31.58
65	25.95	25.51	25.13	27.27	26.1	25.41	27.59	26.54	25.88	28.74	27.98	26.41	25.44	27.89	30.05	31.96
70	26.25	25.51	25.17	27.46	26.1	25.46	27.66	26.64	25.9	28.91	28	26.54	25.56	27.89	30.27	32.22
75	26.08	25.44	25.2	27.49	26.17	25.44	27.79	26.81	25.98	28.94	28.13	26.61	25.54	28.13	30.4	32.47
80	26.1	25.61	25.23	27.66	26.25	25.36	27.86	26.69	26.12	29.17	28.33	26.81	25.54	28.33	30.64	32.81
85	26.12	25.59	25.2	27.69	26.27	25.49	28.08	26.81	26	29.25	28.2	26.79	25.46	28.49	30.79	33.01
90	26.33	25.51	25.27	27.91	26.41	25.46	28.05	26.66	26.1	29.4	28.35	26.89	25.61	28.69	30.94	33.2
95	26.25	25.61	25.23	27.81	26.46	25.61	28.1	26.91	26.2	29.35	28.49	26.98	25.64	28.89	30.99	33.47
100	26.25	25.61	25.33	27.91	26.44	25.61	28.1	26.92	26.1	29.61	28.54	26.91	25.51	28.96	31.1	33.65
105	26.27	25.59	25.33	28.02	26.56	25.59	28.17	27.05	26.17	29.71	28.71	26.91	25.51	29	31.3	33.91
110	26.25	25.71	25.17	28.1	26.46	25.66	28.35	27.25	26.33	29.84	28.76	27.27	25.44	29.27	31.27	33.96
115	26.41	25.66	25.33	27.98	26.46	25.56	28.4	27.15	26.38	29.79	28.71	26.86	25.49	29.33	31.33	34.19
120	26.25	25.46	25.36	28.1	26.44	25.51	28.35	27.08	26.25	29.76	28.86	27	25.41	29.5	31.61	34.11

Table A1.12: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	26.17	25.49	25.35	28.27	26.71	25.69	28.42	27.15	26.49	30.1	28.94	27.33	25.49	29.54	31.55	34.35
130	26.23	25.56	25.23	28.15	26.61	25.76	28.45	27.2	26.3	30.08	29.1	27.05	25.56	29.61	31.45	34.38
135	26.38	25.49	25.25	28.08	26.56	25.49	28.56	27.2	26.41	30.23	29	27.15	25.51	29.66	31.66	34.55
140	26.44	25.46	25.41	28.15	26.54	25.66	28.69	27.23	26.56	30.3	29.17	27.51	25.49	29.84	31.66	34.67
145	26.35	25.64	25.2	28.1	26.54	25.64	28.64	27.27	26.3	30.15	28.94	27.33	25.35	29.79	31.64	34.79
150	26.27	25.44	25.25	28.23	26.46	25.59	28.66	27.2	26.41	30.17	29	27.25	25.46	29.99	31.71	34.7
155	26.35	25.56	25.27	28.2	26.74	25.66	28.59	27.27	26.35	30.48	29.05	27.35	25.36	29.91	31.76	34.84
160	26.27	25.69	25.27	28.17	26.56	25.64	28.76	27.3	26.44	30.33	29.05	27.4	25.36	30.04	31.61	35.01
165	26.2	25.51	25.23	28.2	26.64	25.56	28.74	27.15	26.41	30.4	29.13	27.51	25.49	30.04	31.64	34.89
170	26.27	25.54	25.33	28.17	26.61	25.59	28.56	27.15	26.3	30.33	29.1	27.54	25.56	30.01	31.81	35.01
175	26.05	25.56	25.2	28.15	26.59	25.61	28.69	27.37	26.49	30.33	29.25	27.27	25.46	30.27	31.81	34.91
180	26.35	25.39	25.25	28.2	26.44	25.64	28.64	27.27	26.46	30.25	29.08	27.33	25.44	30.1	31.79	35.06
185	26.3	25.44	25.39	28.1	26.54	25.51	28.59	27.17	26.41	30.35	29.13	27.33	25.49	30.2	31.64	35.06

Table A2.1: Experimental Data for Medium Sphere, $d_p = 3.87$ cm.
Run # 1: Re = 1065.9 $Q_w = 179.2$ W/m^2 $T_{amb} = 25.5$ °C.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	23.98	24.13	23.98	23.92	23.98	24.08	24.17	24.17	24.39	24.39	24.39	24.34	23.9	24.39	24.44	24.49
5	24	23.95	23.95	24.15	24.05	24.1	24.44	24.3	24.39	24.59	24.59	24.25	24.25	24.49	25.27	25.41
10	24.27	24.23	24.08	24.56	23.98	24.13	24.71	24.56	24.54	25.02	24.83	24.54	24.54	24.79	25.95	26.61
15	24.39	24.25	24.2	24.92	24.44	24.25	25.33	24.87	24.81	25.74	25.39	24.71	24.56	25.2	26.89	27.84
20	24.71	24.46	24.36	25.2	24.61	24.41	25.79	25.3	24.92	26.17	25.79	25.08	24.79	25.84	27.66	28.86
25	24.81	24.66	24.41	25.49	24.71	24.46	26.23	25.44	25.23	26.49	26.15	25.36	24.87	26.05	28.15	29.81
30	24.71	24.66	24.51	25.59	24.66	24.46	26.39	25.74	25.51	26.95	26.54	25.66	24.92	26.54	28.69	30.52
35	24.83	24.64	24.64	25.81	24.79	24.54	26.76	25.71	25.61	27.2	26.79	26	24.92	26.74	29.05	31.35
40	24.95	24.66	24.71	26.05	24.95	24.61	27.13	26	25.69	27.44	27.1	26.12	25.15	27.2	29.51	32.09
45	25	24.81	24.61	26.08	24.9	24.81	27.13	26.08	25.79	27.71	27.13	26.27	25.15	27.37	29.61	32.55
50	24.85	24.71	24.71	26.17	25.1	24.85	27.33	26.17	25.84	27.81	27.33	26.41	25.2	27.66	29.86	33.11
55	25.02	24.87	24.69	26.2	25.13	24.79	27.44	26.2	25.9	27.98	27.54	26.54	25.02	27.94	29.96	33.55
60	25	24.81	24.46	26.27	25.15	24.85	27.51	26.38	25.92	28.15	27.61	26.66	24.95	28.15	30.23	33.67
65	25.02	24.79	24.59	26.2	25.23	24.74	27.54	26.44	26	28.23	27.74	26.64	24.74	28.4	30.3	34.01
70	24.95	24.81	24.71	26.38	25.3	24.95	27.76	26.51	25.98	28.49	27.76	26.76	25.1	28.4	30.48	34.55
75	24.9	24.76	24.66	26.3	25.15	24.76	27.66	26.3	26.08	28.45	27.76	26.81	24.76	28.45	30.27	34.5
80	25.02	24.83	24.69	26.39	25.27	24.87	27.69	26.54	26	28.38	27.84	26.69	24.92	28.66	30.17	34.47
85	25.1	24.9	24.61	26.33	25.1	24.9	27.76	26.41	26.08	28.49	27.89	26.71	24.85	28.79	30.45	34.91
90	24.92	24.79	24.69	26.39	25.17	24.98	27.74	26.59	26.05	28.71	27.95	26.98	24.92	28.81	30.64	35.09
95	24.85	24.76	24.71	26.27	25.1	24.95	27.66	26.51	26.08	28.59	27.95	27.1	25.05	28.74	30.56	34.96
100	24.98	24.87	24.69	26.35	25.17	24.83	27.71	26.49	26.1	28.51	27.98	27.08	24.79	29.08	30.64	34.99
105	25.15	24.85	24.76	26.38	25.15	24.81	27.81	26.61	26.05	28.76	28.15	27.08	24.92	29.05	30.74	35.19
110	25.2	24.85	24.66	26.51	25.15	25	27.91	26.56	26.27	28.74	28.1	27.1	24.85	29.2	30.71	35.38
115	24.92	24.79	24.59	26.54	25.23	24.83	27.91	26.59	26.17	28.69	28.2	27	25.05	29.4	30.81	35.55
120	24.92	24.87	24.79	26.44	25.17	24.98	27.94	26.86	26.25	28.81	28.23	26.89	24.98	29.38	30.84	35.78

Table A2.1: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	$T_w 1$	$T_w 2$
125	25	24.69	24.87	26.27	25.3	24.95	27.95	26.51	26.33	28.91	28.15	27	25	29.3	30.86	35.7
130	25.05	24.71	24.61	26.56	25.35	24.9	27.91	26.56	26.25	28.86	28.27	26.92	24.79	29.38	30.79	35.72
135	25.02	24.92	24.64	26.35	25.23	24.92	28.08	26.59	26.08	28.74	28.3	27.05	24.85	29.59	30.91	35.96
140	25.02	24.83	24.74	26.35	25.27	24.98	28.17	26.69	26.27	28.86	28.3	27.23	25.1	29.56	30.94	35.99
145	25.1	24.76	24.66	26.51	25.25	24.95	28.1	26.66	26.35	28.81	28.17	27.17	25.13	29.56	30.99	35.99
150	24.98	24.83	24.71	26.49	25.33	24.98	27.98	26.59	26.25	28.96	28.23	27.33	24.98	29.61	30.99	35.89
155	25	24.85	24.76	26.41	25.3	24.81	28	26.71	26.27	28.79	28.35	27.3	25.1	29.59	30.96	36.19
160	25	24.95	24.71	26.46	25.3	24.95	27.95	26.76	26.41	28.89	28.2	27.3	24.95	29.59	30.86	36.06
165	24.98	24.79	24.74	26.59	25.33	24.92	28.02	26.79	26.2	28.79	28.23	27.13	24.92	29.64	30.91	36.01
170	25.02	24.92	24.76	26.54	25.33	24.9	28.08	26.66	26.23	29	28.25	27.2	24.81	29.71	30.99	36.09
175	24.9	24.85	24.71	26.46	25.3	25.1	28.05	26.71	26.2	28.99	28.38	27.13	25.17	29.69	30.96	36.06
180	25.08	24.95	24.85	26.51	25.23	25	28.08	26.66	26.25	28.96	28.27	27.23	25.08	29.71	30.94	36.16
185	25.05	24.71	24.76	26.41	25.3	25	28	26.76	26.17	28.96	28.15	27.23	25	29.61	30.84	36.21
190	25.08	24.92	24.69	26.59	25.33	24.98	28.17	26.74	26.17	29.1	28.35	27.25	24.81	29.84	31.06	36.34
195	25.13	24.83	24.74	26.59	25.35	25.08	28.05	26.79	26.27	29	28.4	27.3	25.25	29.86	31.04	36.36
200	24.98	24.98	24.74	26.64	25.36	24.92	28.23	26.64	26.39	29.02	28.4	27.2	24.71	29.89	30.96	36.29
205	25.13	24.81	24.81	26.66	25.27	25.08	28.3	26.81	26.3	29.13	28.49	27.4	25.17	29.89	31.2	36.29
210	25.23	24.83	24.83	26.59	25.46	24.92	28.17	26.74	26.3	29.1	28.48	27.27	25.13	29.91	31.17	36.45
215	25.02	24.81	24.81	26.66	25.33	25.02	28.23	26.76	26.33	29.1	28.45	27.37	24.85	29.86	31.12	36.36
220	25.15	24.76	24.76	26.61	25.35	24.95	28.15	26.81	26.44	29.02	28.51	27.27	25.17	29.84	31.15	36.26
225	25.1	24.95	24.87	26.56	25.35	25.1	28.25	26.89	26.3	28.99	28.42	27.44	25.27	29.89	31.25	36.53
230	25.15	24.95	24.76	26.66	25.39	25	28.3	26.81	26.35	29.1	28.56	27.33	24.87	29.91	31.23	36.5
235	25.23	25.1	24.85	26.76	25.46	25.1	28.33	26.91	26.49	29.27	28.61	27.46	25.23	29.99	31.4	36.63
240	25.1	24.9	24.76	26.71	25.49	25.15	28.35	26.91	26.38	29.23	28.54	27.44	24.95	29.94	31.25	36.67
245	25.2	24.9	24.85	26.81	25.39	25.05	28.35	27	26.23	29.27	28.69	27.3	25.15	30.04	31.3	36.75
250	25.23	25.02	25.02	26.84	25.41	25.08	28.42	26.98	26.33	29.25	28.64	27.59	25.1	30.1	31.27	36.75

Table A2.2: Experimental Data for Medium Sphere, $d_p = 3.87$ cm.
Run # 2: Re = 880.6 $Q_w = 179.2$ W/m^2 $T_{amb} = 24.5$ °C.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	22.88	22.92	22.77	22.58	22.88	23.17	22.88	23.08	23.51	23.41	23.46	23.51	23.26	23.95	23.23	23.66
5	23.26	23.26	23.31	23.26	23.31	23.41	23.56	23.41	23.74	23.83	23.79	23.92	23.64	24.17	24.56	25.08
10	23.66	23.51	23.41	23.8	23.56	23.41	24.2	23.9	23.92	24.46	24.36	23.92	23.79	24.56	25.56	26.39
15	23.85	23.61	23.66	24.39	23.76	23.61	24.98	24.44	24.36	25.35	25.15	24.41	24.23	25	26.98	27.59
20	24.08	23.83	23.74	24.76	24.13	23.69	25.49	24.81	24.61	25.9	25.46	24.81	24.27	25.46	27.59	28.81
25	24.23	24.02	23.79	25.15	24.17	23.83	26.1	25.25	24.66	26.27	25.88	25.05	24.23	25.92	28.27	29.86
30	24.27	24.08	23.85	25.36	24.23	23.92	26.2	25.17	24.92	26.69	26.3	25.36	24.25	26.25	28.81	30.91
35	24.39	24.15	23.95	25.36	24.44	24	26.71	25.56	25.1	27.02	26.69	25.64	24.31	26.69	29.2	31.71
40	24.41	24	23.95	25.54	24.41	24.08	26.79	25.49	25.17	27.35	26.74	25.81	24.3	27	29.56	32.4
45	24.39	24.15	23.95	25.81	24.64	24.2	27.15	25.76	25.36	27.59	27.2	26	24.25	27.4	29.91	33.11
50	24.44	24	24	25.86	24.59	24.15	27.3	26	25.41	27.84	27.35	26.15	24.44	27.74	30.25	33.67
55	24.39	24.2	23.95	25.95	24.69	24.3	27.49	26.1	25.71	28.13	27.42	26.2	24.39	27.98	30.3	34.14
60	24.61	24.31	24.08	26.08	24.56	24.41	27.59	26.17	25.41	28.3	27.59	26.39	24.39	28.25	30.61	34.72
65	24.54	24.25	24.1	26.05	24.64	24.39	27.69	26.35	25.51	28.35	27.69	26.56	24.39	28.45	30.94	34.89
70	24.69	24.34	24.05	26.1	24.69	24.34	27.94	26.25	25.79	28.48	27.81	26.66	24.51	28.66	31.04	35.38
75	24.46	24.36	24.02	26.33	24.95	24.36	28.05	26.38	25.9	28.71	28.02	26.84	24.39	28.81	31.48	35.7
80	24.66	24.36	24.1	26.38	24.76	24.41	28.15	26.46	25.79	28.89	28.25	26.81	24.61	29.1	31.38	36.09
85	24.66	24.31	24.17	26.38	24.95	24.46	28.25	26.61	25.71	28.99	28.3	27.05	24.61	29.3	31.48	36.36
90	24.59	24.44	24.3	26.49	25.02	24.59	28.27	26.74	25.98	29.05	28.38	27.08	24.76	29.15	31.64	36.63
95	24.66	24.54	24.34	26.51	25.15	24.61	28.35	26.56	26.02	29.3	28.49	27.33	24.61	29.61	31.74	36.95
100	24.59	24.34	24.3	26.54	25.08	24.64	28.42	26.69	26.02	29.25	28.51	27.23	24.76	29.86	31.86	37.05
105	24.69	24.49	24.31	26.69	24.98	24.54	28.42	26.74	26.12	29.4	28.54	27.27	24.44	30.01	31.89	37.16
110	24.69	24.39	24.2	26.59	25.02	24.59	28.51	26.79	25.95	29.48	28.61	27.27	24.64	30.13	32.06	37.34
115	24.71	24.36	24.36	26.76	25.15	24.51	28.54	26.81	26.02	29.54	28.69	27.35	24.41	29.99	32.13	37.64
120	24.66	24.41	24.41	26.61	25.05	24.66	28.54	26.86	26.08	29.5	28.69	27.4	24.56	30.15	32.22	37.64

Table A2.2: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	24.66	24.44	24.3	26.66	25.05	24.59	28.64	26.91	26.17	29.64	28.81	27.44	24.46	30.25	32.11	37.95
130	24.76	24.61	24.31	26.56	25.05	24.61	28.69	26.86	26.12	29.59	28.76	27.25	24.49	30.25	32.11	37.9
135	24.69	24.54	24.34	26.66	25.08	24.59	28.81	26.89	26.2	29.51	28.76	27.42	24.54	30.27	32.22	38.15
140	24.69	24.34	24.3	26.59	25.02	24.54	28.61	26.79	26.15	29.69	28.89	27.4	24.66	30.55	32.13	38.1
145	24.74	24.59	24.39	26.86	25.1	24.74	28.91	26.95	26.33	29.74	28.84	27.49	24.66	30.5	32.4	38.22
150	24.74	24.39	24.25	26.64	25.13	24.79	28.71	26.98	26.25	29.66	28.91	27.42	24.69	30.52	32.25	38.17
155	24.85	24.41	24.36	26.76	25.3	24.66	28.79	26.95	26.2	29.84	28.89	27.74	24.61	30.59	32.33	38.36
160	24.79	24.49	24.34	26.56	25.13	24.59	28.76	26.95	26.33	30.01	28.96	27.42	24.59	30.76	32.4	38.34
165	24.79	24.49	24.39	26.69	25.13	24.64	28.81	27.02	26.15	29.84	29.02	27.61	24.64	30.79	32.33	38.41
170	24.74	24.59	24.39	26.69	25.17	24.69	28.76	27.02	26.3	29.76	29	27.61	24.54	30.74	32.37	38.39
175	24.81	24.46	24.31	26.71	25.1	24.51	28.69	26.91	26.08	29.86	28.96	27.61	24.39	30.86	32.35	38.44
180	24.74	24.36	24.23	26.64	25.02	24.74	28.66	26.84	26.17	29.86	29	27.56	24.69	30.86	32.4	38.36
185	24.74	24.46	24.36	26.69	25.27	24.64	28.81	27.08	26.3	29.86	29.05	27.66	24.64	30.81	32.4	38.59
190	24.83	24.49	24.34	26.86	25.17	24.69	28.84	27.05	26.3	29.99	28.96	27.74	24.61	30.89	32.42	38.54
195	24.9	24.56	24.36	26.89	25.27	24.66	28.76	27.08	26.39	29.91	29.05	27.51	24.92	31.04	32.55	38.54
200	24.98	24.74	24.41	26.98	25.27	24.79	28.91	27.23	26.39	29.96	29.1	27.71	24.69	30.96	32.5	38.51
205	25.1	24.71	24.46	26.95	25.25	24.81	29.08	27.2	26.38	30.17	29.13	27.69	24.76	31.1	32.69	38.66
210	25.1	24.66	24.46	27.02	25.25	24.81	28.96	27.27	26.39	30.23	29.1	27.84	25	30.99	32.76	38.74
215	24.98	24.74	24.56	27.02	25.41	24.83	29.15	27.23	26.38	30.08	29.27	27.69	24.98	31.2	32.74	39.03
220	25.05	24.71	24.61	27.02	25.54	24.95	29.05	27.23	26.33	30.23	29.17	27.84	24.76	31.12	32.84	39.03
225	25	24.66	24.56	27.02	25.46	24.95	29.2	27.23	26.51	30.33	29.33	27.79	25.05	31.2	32.76	39.08
230	25.17	24.79	24.49	27.15	25.39	24.87	29.08	27.35	26.46	30.38	29.42	27.94	24.76	31.2	32.71	39.03
235	25.05	24.64	24.59	27.2	25.44	24.9	29.17	27.25	26.49	30.15	29.3	27.71	24.81	31.27	32.91	39.05
240	25.13	24.83	24.59	27.1	25.27	24.83	29.1	27.51	26.49	30.17	29.27	27.89	24.95	31.38	32.71	39.08
245	25.1	24.66	24.56	27.02	25.35	24.85	29.2	27.27	26.56	30.2	29.25	27.74	24.92	31.3	32.84	39.2
250	24.95	24.56	24.51	27.08	25.44	24.9	29.05	27.49	26.46	30.1	29.25	27.95	24.87	31.3	32.74	39.15
255	24.92	24.69	24.44	26.95	25.2	24.83	29.02	27.25	26.49	30.15	29.35	27.95	24.87	31.38	32.81	38.91
260	24.92	24.69	24.59	27.05	25.25	24.79	29.08	27.3	26.39	30.01	29.45	27.95	24.51	31.27	32.66	39.05

Table A2.3: Experimental Data for Medium Sphere, $d_p = 3.87$ cm.
Run # 3: Re = 672.6 $Q_w = 179.2$ W/m^2 $T_{amb} = 24.2$ °C.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	23.23	23.26	23.13	23.08	23.13	23.39	23.23	23.23	23.59	23.83	23.64	23.54	23.49	23.79	23.49	23.54
5	23.49	23.29	23.05	23.34	23.15	23.1	23.49	23.54	23.59	23.88	23.83	23.69	23.88	23.83	24.69	25.02
10	23.61	23.61	23.41	24	23.56	23.31	24.34	24.05	23.95	24.44	24.34	23.8	23.85	24.2	26.02	26.49
15	23.8	23.51	23.26	24.27	23.56	23.41	25	24.31	24.15	25.13	24.92	24.34	23.71	24.69	27.13	27.89
20	23.88	23.64	23.49	24.76	23.83	23.74	25.59	24.76	24.39	25.79	25.49	24.83	24.05	25.33	28.13	29.2
25	23.9	23.66	23.49	24.85	23.8	23.66	25.92	25	24.46	26.3	26	25	23.83	25.61	28.86	30.45
30	24.1	23.71	23.61	25.36	24.1	23.8	26.56	25.23	24.76	26.84	26.49	25.35	23.92	26.1	29.71	31.48
35	24.13	23.74	23.49	25.54	24.23	23.69	26.92	25.44	24.9	27.35	26.74	25.64	24.02	26.54	30.13	32.66
40	24.15	23.92	23.59	25.59	24.3	23.88	27	25.64	24.98	27.33	26.91	25.46	23.85	26.56	30.3	32.79
45	24.1	23.76	23.51	25.61	24.3	23.71	27.25	25.76	25.15	27.79	27.17	25.84	23.88	27.13	30.56	33.42
50	24.27	23.83	23.64	25.98	24.41	23.83	27.51	25.92	25.33	28.15	27.61	26.05	23.95	27.49	31.1	34.45
55	24.2	23.9	23.61	25.95	24.39	23.95	27.79	26	25.2	28.49	27.69	26.49	24.13	27.79	31.55	35.06
60	24.36	24.05	23.85	26.27	24.46	24	28.13	26.27	25.59	28.76	27.91	26.51	24.13	28.27	31.79	35.63
65	24.15	24	23.66	26.39	24.54	23.95	28.33	26.2	25.64	28.86	28.1	26.76	23.98	28.51	32.09	36.16
70	24.41	23.88	23.79	26.51	24.61	24.13	28.4	26.46	25.59	29.13	28.38	26.98	24.13	28.81	32.45	36.75
75	24.41	24.02	23.79	26.41	24.61	24.08	28.35	26.51	25.74	29.08	28.48	26.76	24.08	28.99	32.5	36.8
80	24.3	24	23.8	26.54	24.64	24.2	28.66	26.44	25.74	29.48	28.66	26.74	23.92	29.23	32.71	37.39
85	24.34	24.05	23.88	26.49	24.74	24.15	28.89	26.59	25.88	29.59	28.61	26.98	24	29.54	32.94	37.83
90	24.39	24	23.85	26.81	24.81	24.3	28.96	26.71	25.88	29.79	28.86	27.37	24	29.69	33.09	38.2
95	24.46	23.98	23.79	26.69	24.85	24.27	29.02	26.86	25.84	29.79	29.02	27.46	24.2	29.94	33.14	38.64
100	24.44	24.05	23.8	26.98	24.83	24.25	29.15	26.79	26.05	30.1	29.08	27.3	24.2	30.25	33.45	38.91
105	24.44	24	23.74	26.74	24.79	24.25	29.23	26.74	25.98	30.08	29.13	27.42	24.1	30.35	33.28	38.95
110	24.51	24.08	23.74	26.89	24.87	24.36	29.13	27.02	26.05	30.3	29.27	27.79	24.05	30.4	33.42	39.22
115	24.46	24.08	23.85	26.91	24.95	24.23	29.23	26.95	26.23	30.27	29.27	27.61	24.15	30.59	33.47	39.47
120	24.46	24.08	23.8	26.86	24.9	24.23	29.3	26.86	26.1	30.35	29.38	27.42	24.15	30.79	33.55	39.45

Table A2.3: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	$T_w 1$	$T_w 2$
125	24.64	23.9	23.85	26.91	24.98	24.3	29.25	27	26.12	30.38	29.35	27.74	24.13	30.81	33.55	39.74
130	24.46	24.05	23.85	27.05	25	24.31	29.4	27	26.05	30.45	29.5	27.89	24.08	30.91	33.74	39.94
135	24.54	24.05	23.85	27.13	25.08	24.3	29.56	27.13	26.27	30.56	29.5	27.86	24.08	31.17	33.71	40.14
140	24.69	24.05	23.9	27.17	24.98	24.34	29.45	27.05	26.15	30.45	29.59	27.84	24.2	31.2	33.74	40.16
145	24.61	24.23	23.98	27.1	24.9	24.46	29.59	27	26.17	30.56	29.61	27.95	24.3	31.45	33.89	40.4
150	24.64	24.17	24.08	27.27	24.98	24.36	29.71	27.23	26.2	30.81	29.54	27.89	24.23	31.48	33.91	40.47
155	24.76	24.3	24.05	27.15	25	24.44	29.64	27.2	26.3	30.74	29.76	28.13	24.39	31.61	34.16	40.7
160	24.83	24.25	23.95	27.33	25.17	24.39	29.74	27.25	26.38	30.74	29.81	28.15	24.34	31.69	34.14	40.72
165	24.69	24.34	24.05	27.25	25.15	24.39	29.69	27.3	26.41	30.79	29.66	28.15	24.39	31.69	34.25	40.8
170	24.76	24.23	24.13	27.37	25.13	24.51	29.66	27.37	26.41	31.08	30.01	28.2	24.31	31.79	34.19	40.86
175	24.87	24.34	24.15	27.37	25.17	24.59	29.91	27.42	26.41	31.06	30.05	28.3	24.51	31.94	34.42	41.19
180	24.74	24.49	24.1	27.33	25.23	24.64	29.91	27.27	26.49	30.96	29.94	28.17	24.41	31.99	34.25	41.06
185	24.81	24.34	24.1	27.49	25.25	24.59	29.89	27.49	26.44	31.1	30.04	28.33	24.36	32.01	34.25	40.94
190	24.98	24.49	24.2	27.33	25.41	24.69	29.91	27.27	26.49	31.08	29.96	28.23	24.49	32.01	34.22	41.09
195	24.66	24.46	24.25	27.49	25.3	24.66	29.89	27.44	26.56	31.06	30.05	28.4	24.66	32.28	34.47	41.29
200	24.85	24.31	24.13	27.37	25.23	24.66	30.05	27.51	26.54	31.04	30.13	28.27	24.64	32.15	34.4	41.39
205	24.92	24.46	24.23	27.51	25.36	24.71	29.91	27.51	26.54	30.99	30.17	28.33	24.54	32.37	34.55	41.34
210	24.81	24.61	24.27	27.51	25.36	24.41	30.01	27.42	26.54	31.12	30.08	28.27	24.44	32.28	34.45	41.34
215	24.9	24.46	24.25	27.54	25.2	24.46	29.94	27.54	26.56	31.23	30.05	28.49	24.27	32.2	34.16	41.26
220	24.83	24.39	24.15	27.4	25.35	24.69	29.89	27.44	26.59	31.1	30.08	28.23	24.39	32.37	34.16	41.34
225	24.9	24.36	24.23	27.37	25.41	24.66	29.91	27.51	26.59	31.1	30.08	28.33	24.41	32.28	34.2	41.36
230	25.02	24.34	24.3	27.56	25.33	24.64	29.86	27.56	26.69	31.04	30.17	28.3	24.54	32.47	34.45	41.26
235	25.02	24.46	24.13	27.46	25.27	24.69	29.96	27.37	26.49	31.25	30.08	28.23	24.39	32.37	34.22	41.16
240	24.9	24.46	24.31	27.59	25.2	24.61	29.99	27.4	26.69	31.2	30.08	28.48	24.66	32.5	34.35	41.24
245	25.02	24.51	24.23	27.46	25.36	24.66	29.96	27.46	26.61	31.1	30.01	28.2	24.46	32.35	34.2	41.24
250	24.81	24.39	24.15	27.35	25.35	24.59	29.89	27.49	26.46	31.12	30.15	28.3	24.59	32.35	34.38	41.36

Table A2.4: Experimental Data for Medium Sphere, $d_p = 3.87$ cm.
Run # 4: Re = 447.4 $Q_w = 179.2$ W/m^2 $T_{amb} = 24.8$ °C.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	23.88	23.88	23.83	24.02	23.92	24.13	24.17	24.17	24.54	24.59	24.54	24.2	23.31	24.76	24.59	24.81
5	23.85	23.95	23.8	23.95	23.95	23.95	24.34	24.15	24.49	24.66	24.76	24.34	24.15	24.81	25.64	26.08
10	24	24	23.95	24.39	24.05	24.15	24.92	24.64	24.59	25.25	25.02	24.69	24.05	25.15	26.89	27.69
15	24.23	24.17	23.92	25	24.27	24.17	25.84	25.05	25.02	25.88	25.66	24.87	24.39	25.46	28.23	28.94
20	24.34	23.95	23.95	25.36	24.49	24.1	26.56	25.23	25.1	26.69	26.35	25.49	24.31	26	29.38	30.45
25	24.36	24.23	24.08	26.08	24.71	24.36	27.17	25.64	25.33	27.4	27	25.95	24.08	26.39	30.45	31.91
30	24.56	24.13	23.98	26.08	24.81	24.36	27.37	25.74	25.41	27.49	26.91	25.9	24.41	26.59	30.59	32.25
35	24.56	24.17	24.23	26.33	24.85	24.41	27.95	26.08	25.59	28.02	27.64	26.12	24.27	27.13	31.58	33.6
40	24.64	24.25	24.1	26.69	25.02	24.59	28.54	26.3	25.64	28.64	27.94	26.49	24.46	27.69	32.28	34.7
45	24.59	24.34	24.15	26.74	25.1	24.54	28.86	26.49	25.86	29.15	28.59	26.84	24.31	28.08	32.86	35.81
50	24.74	24.3	23.95	27.23	25.27	24.69	29.48	26.84	26.1	29.61	29	27.2	24.34	28.54	33.81	36.8
55	24.83	24.3	24.05	27.27	25.36	24.64	29.71	26.92	26.38	30.08	29.33	27.51	24.27	28.99	34.09	37.8
60	24.83	24.39	24.3	27.46	25.27	24.69	29.71	26.98	26.33	30.2	29.33	27.37	24.46	28.94	34.3	37.72
65	24.81	24.44	24.25	27.71	25.54	24.76	30.25	27.05	26.54	30.42	29.64	27.79	24.46	29.54	34.74	38.74
70	24.92	24.49	24.25	27.76	25.51	24.74	30.42	27.23	26.54	30.91	29.94	27.94	24.23	29.79	35.04	39.33
75	24.98	24.49	24.2	28.15	25.69	24.79	30.76	27.51	26.69	31.23	30.2	28.17	24.36	30.35	35.63	40.21
80	25.05	24.46	24.34	27.98	25.64	24.85	30.99	27.59	26.79	31.52	30.5	28.56	24.44	30.71	35.99	40.8
85	25.15	24.61	24.13	28.38	25.74	24.9	31.4	27.79	26.89	31.74	30.71	28.51	24.44	30.86	36.31	41.36
90	25.23	24.64	24.27	28.3	25.81	25.08	31.61	27.91	26.91	32.15	30.91	28.84	24.44	31.27	36.47	41.95
95	25.17	24.46	24.23	28.4	25.9	24.92	31.52	27.81	27.1	32.11	31.04	28.99	24.54	31.27	36.53	41.95
100	25.17	24.56	24.36	28.45	26.1	25.02	31.76	27.81	27.08	32.37	31.15	28.91	24.49	31.58	36.88	42.49
105	25.3	24.59	24.49	28.79	26.02	24.92	31.89	27.98	27	32.53	31.25	29.1	24.81	31.96	37.03	43.03
110	25.33	24.64	24.51	28.84	26.1	25.23	32.06	28.15	27.2	32.81	31.52	29.35	24.71	32.35	37.26	43.44
115	25.41	24.83	24.46	28.79	26.05	25.13	31.96	28.05	27.15	32.86	31.52	29.1	24.56	32.2	37.31	43.39
120	25.51	24.87	24.44	29.84	26.33	25.33	32.3	28.45	27.27	33.11	31.81	29.56	24.83	32.37	37.61	43.9

Table A2.4: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	25.44	24.71	24.44	29.64	26.39	25.3	32.64	28.38	27.44	33.33	31.94	29.76	24.76	32.76	38.13	44.44
130	25.44	24.87	24.54	30.25	26.41	25.25	32.94	28.66	27.56	33.4	32.25	30.01	24.87	32.94	38.3	44.8
135	25.54	24.85	24.66	29.86	26.54	25.25	33.09	28.56	27.69	33.65	32.25	30.05	24.81	33.22	38.61	45.16
140	25.49	24.79	24.49	30.48	26.61	25.39	33.16	28.76	27.79	33.94	32.6	30.1	24.81	33.38	38.86	45.67
145	25.64	24.95	24.56	30.08	26.49	25.39	33.38	28.74	27.86	34.06	32.66	30.2	24.76	33.65	38.89	46.03
150	25.51	25.05	24.51	30.64	26.74	25.51	33.42	29.02	27.89	34.35	32.84	30.35	24.66	33.89	38.91	46.19
155	25.51	24.92	24.49	30.05	26.76	25.51	33.4	28.91	27.94	34.42	32.86	30.3	24.51	34.11	39.03	46.61
160	25.56	24.85	24.56	30.84	26.74	25.46	33.74	29.02	27.86	34.38	32.94	30.61	24.76	34.28	39.45	46.75
165	25.54	24.92	24.54	30.25	26.66	25.49	33.67	28.96	27.86	34.6	33.14	30.66	24.66	34.65	39.45	46.87
170	25.71	24.85	24.61	30.94	26.79	25.61	33.84	29.27	28	34.65	33.28	30.81	24.51	34.47	39.33	47.31
175	25.56	24.85	24.51	30.48	26.89	25.36	33.79	29.13	28	34.67	33.09	30.94	24.79	34.76	39.5	47.34
180	25.66	24.79	24.56	30.99	26.81	25.56	33.99	29.23	28.02	34.94	33.4	30.84	24.92	34.81	39.66	47.39
185	25.69	24.83	24.54	30.45	26.76	25.69	33.81	29.1	28.08	34.91	33.35	31.12	24.98	35.04	39.71	47.74
190	25.69	24.92	24.59	31.2	27	25.59	34.14	29.25	28.15	35.11	33.65	30.91	24.81	35.16	39.74	47.75
195	25.66	25.1	24.66	30.74	26.92	25.61	34.14	29.33	28.17	34.99	33.53	30.96	24.9	35.3	39.89	47.9
200	25.69	25.13	24.74	31.3	27.05	25.69	34.28	29.3	28.23	35.28	33.55	31.3	24.83	35.28	39.99	48.05
205	25.79	25.02	24.64	30.71	27.05	25.46	34.19	29.23	28.25	35.25	33.69	31.17	24.79	35.47	39.84	48.15
210	25.81	25.1	24.76	31.35	27.02	25.81	34.45	29.5	28.35	35.3	33.76	31.2	24.85	35.58	40.16	48.41
215	25.69	25.15	24.71	30.84	26.98	25.76	34.25	29.45	28.42	35.24	33.89	31.35	25	35.86	40.21	48.46
220	25.84	25.23	24.83	31.3	27.15	25.84	34.6	29.51	28.42	35.5	33.86	31.45	24.76	35.86	40.25	48.62
225	25.79	25.1	24.69	30.96	27.13	25.79	34.42	29.35	28.35	35.35	33.89	31.42	25	35.99	40.33	48.85
230	25.92	25.17	24.74	31.52	27.2	25.74	34.58	29.5	28.4	35.63	34.2	31.58	24.9	35.94	40.28	48.99
235	25.74	25.15	24.71	31.04	27.08	25.79	34.53	29.5	28.48	35.55	34.01	31.45	24.83	36.24	40.19	48.92
240	25.81	25.1	24.76	31.35	27.17	25.66	34.58	29.64	28.51	35.65	34.09	31.5	24.74	36.24	40.42	49.16
245	25.79	25.15	24.69	31.04	27.13	25.88	34.63	29.54	28.48	35.7	34.01	31.6	24.79	36.34	40.3	49.16
250	25.9	25.2	24.61	31.5	27.27	25.71	34.76	29.64	28.56	35.86	34.22	31.5	24.64	36.29	40.6	49.11
255	25.76	25.08	24.74	31.01	27	26	34.7	29.48	28.48	35.67	34.14	31.64	24.74	36.36	40.55	49.19
260	25.76	25.13	24.71	31.33	27.15	25.76	34.76	29.76	28.48	35.6	34.28	31.6	24.79	36.55	40.6	49.31

Table A2.4: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	$T_w 1$	$T_w 2$
265	25.66	25	24.76	31.04	27.02	25.76	34.5	29.61	28.56	35.63	34.2	31.71	24.76	36.53	40.5	49.34
270	25.76	25.17	24.61	31.23	27.08	25.9	34.65	29.71	28.45	35.8	34.25	31.84	24.81	36.6	40.4	49.53
275	25.76	24.98	24.61	31.06	27	25.66	34.55	29.51	28.54	35.6	34.22	31.69	24.61	36.67	40.47	49.42
280	25.71	25.02	24.56	31.33	27.15	25.81	34.84	29.76	28.71	35.78	34.22	31.74	24.81	36.78	40.6	49.47
285	25.69	24.92	24.69	31.01	27	25.79	34.53	29.54	28.42	35.72	34.09	31.5	24.79	36.8	40.55	49.37
290	25.66	25	24.66	31.42	26.98	25.66	34.65	29.61	28.51	35.78	34.2	31.6	24.64	36.85	40.55	49.58

Table A2.5: Experimental Data for Medium Sphere, $d_p = 3.87$ cm.
Run # 5: Re = 1065.9 $Q_w = 79.4$ W/m^2 $T_{amb} = 25.0$ °C.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	22.98	23.13	23.13	23.02	23.31	23.46	23.56	23.46	23.85	23.95	24	24.05	23.02	24.34	23.76	24.34
5	23.51	23.51	23.36	23.46	23.36	23.71	23.61	23.66	23.85	24.05	23.95	23.95	23.76	24.49	24.2	24.74
10	23.71	23.56	23.66	23.71	23.71	23.71	23.9	23.95	24.23	24.31	24.27	24.23	23.92	24.46	24.71	25.1
15	24.15	24	23.71	24.1	23.9	23.8	24.46	24.2	24.23	24.71	24.61	24.46	24.36	24.61	25.2	25.9
20	24.15	24	23.85	24.25	24	23.9	24.44	24.39	24.34	24.79	24.74	24.44	24.3	24.87	25.33	26.08
25	24.34	24.15	24.1	24.34	24.1	24.1	24.87	24.54	24.59	25.08	24.92	24.54	24.49	24.98	25.61	26.44
30	24.49	24.39	24.15	24.64	24.25	24.15	25.02	24.69	24.81	25.27	25.23	24.81	24.61	25.23	26.3	26.98
35	24.51	24.27	24.31	24.76	24.27	24.27	25.3	24.81	24.81	25.59	25.39	25	24.71	25.39	26.33	27.33
40	24.66	24.56	24.41	24.85	24.56	24.36	25.25	24.9	25.02	25.66	25.51	24.98	24.64	25.51	26.56	27.69
45	24.61	24.56	24.27	25.05	24.56	24.46	25.59	25	24.95	25.79	25.69	25.1	24.56	25.74	26.66	27.91
50	24.71	24.61	24.36	25.02	24.46	24.51	25.54	25.08	25.02	25.86	25.66	25.17	24.83	25.66	26.89	28.08
55	24.71	24.51	24.46	25.05	24.56	24.46	25.64	25.1	25.02	26	25.81	25.36	24.87	26	26.95	28.3
60	24.71	24.71	24.51	25.1	24.71	24.56	25.64	25.3	25.15	25.92	25.92	25.44	24.81	25.92	27.02	28.33
65	24.76	24.61	24.51	25.1	24.56	24.56	25.59	25.3	25.02	26.1	25.95	25.27	24.64	26	27.02	28.64
70	24.92	24.69	24.54	25.23	24.74	24.59	25.71	25.27	25.27	26.3	25.9	25.46	24.92	26.05	27.08	28.61
75	24.95	24.71	24.56	25.3	24.81	24.66	25.79	25.44	25.2	26.27	26.12	25.25	24.85	26.33	27.2	28.84
80	24.87	24.71	24.56	25.13	24.76	24.66	25.81	25.46	25.3	26.38	26.12	25.54	25	26.23	27.3	28.89
85	24.83	24.59	24.69	25.36	24.79	24.69	25.9	25.46	25.3	26.41	26.08	25.69	24.9	26.38	27.37	29.25
90	24.85	24.9	24.71	25.3	24.9	24.66	26.08	25.39	25.36	26.39	26.25	25.56	24.85	26.49	27.4	29.38
95	25.1	24.85	24.71	25.46	24.85	24.76	26	25.56	25.51	26.54	26.39	25.71	24.87	26.49	27.33	29.23
100	25.05	24.81	24.51	25.39	24.81	24.76	26.02	25.49	25.35	26.46	26.23	25.74	25.02	26.66	27.37	29.5
105	24.9	24.81	24.71	25.36	24.9	24.61	26.2	25.61	25.51	26.64	26.39	25.86	24.98	26.74	27.46	29.56
110	25.05	24.95	24.85	25.51	25	24.85	26.2	25.66	25.51	26.64	26.54	25.76	24.92	26.59	27.61	29.51
115	24.98	24.92	24.83	25.51	24.87	24.87	26.3	25.56	25.56	26.59	26.2	25.86	24.98	26.69	27.51	29.81
120	25.15	24.95	24.85	25.59	25.1	24.85	26.15	25.59	25.61	26.69	26.54	25.86	25.02	26.74	27.59	29.86

Table A2.5: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	25.08	24.79	24.87	25.35	25.08	24.87	26.41	25.74	25.56	26.89	26.49	25.81	25.13	26.92	27.61	29.76
130	25.13	25.02	24.64	25.54	24.98	25.02	26.27	25.74	25.64	26.71	26.56	25.92	25.08	26.81	27.71	29.89
135	24.92	24.92	24.92	25.51	25.17	24.79	26.2	25.71	25.71	26.92	26.49	26	25.1	26.98	27.74	29.99
140	25.13	24.81	24.81	25.51	25.08	24.9	26.15	25.76	25.81	26.79	26.49	26.05	24.92	27.08	27.61	29.81
145	25.08	24.87	24.79	25.66	24.98	24.87	26.49	25.76	25.59	26.91	26.56	25.98	25.15	27.15	27.74	30.08
150	25.15	24.9	24.85	25.69	25.05	25.05	26.38	25.92	25.76	26.98	26.69	25.86	25.1	27.08	27.74	29.91
155	25.1	25	24.79	25.54	25	24.9	26.38	25.84	25.59	26.91	26.71	26.12	25.08	27.1	27.74	30.04
160	25.05	24.92	24.87	25.59	25.05	25.02	26.56	25.79	25.64	27.05	26.61	26.08	25.1	27.1	27.98	30.23
165	25.17	24.98	24.83	25.71	25.08	25.02	26.44	25.81	25.71	26.89	26.74	26.1	25.2	27.13	27.89	30.1
170	25.15	24.9	24.9	25.69	25.1	25.2	26.46	25.98	25.71	26.92	26.64	26.05	25.13	27.23	27.86	30.35
175	25	25	24.81	25.61	25.2	24.95	26.44	25.86	25.79	26.95	26.61	26.02	25.13	27.15	27.84	30.17
180	25.2	24.95	24.81	25.74	25.1	24.95	26.46	25.92	25.79	27.1	26.71	26.08	25.05	27.25	27.79	30.23
185	25.23	25.02	24.71	25.81	25.08	24.81	26.44	26	25.76	27.02	26.69	25.9	25.2	27.23	27.71	30.27
190	25.05	25.05	24.85	25.84	25.15	24.95	26.41	25.98	25.74	26.95	26.56	26.17	25.33	27.25	27.86	30.3

Table A2.6: Experimental Data for Medium Sphere, $d_p = 3.87$ cm.
Run # 6: Re = 880.6 $Q_w = 79.4\ W/m^2$ $T_{amb} = 25.0\ ^oC$.
Time in (minutes), Temperature in (^oC) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	24	24.2	24.05	24.25	24.1	24.34	24.3	24.39	24.66	24.76	24.71	24.71	23.74	24.87	24.81	25.02
5	24.08	24.17	24.08	24.27	24.13	24.23	24.31	24.27	24.51	24.81	24.71	24.71	24.23	25	25.15	25.49
10	24.23	24.17	24.23	24.31	24.13	24.23	24.76	24.56	24.59	24.98	24.83	24.83	24.39	24.98	25.35	25.98
15	24.39	24.34	24.15	24.64	24.34	24.3	24.87	24.74	24.81	25.25	25.05	24.76	24.31	25.2	25.88	26.59
20	24.44	24.34	24.15	24.79	24.34	24.3	25.13	24.79	24.92	25.46	25.27	24.92	24.69	25.36	26.17	26.91
25	24.49	24.39	24.39	25	24.49	24.3	25.25	25	25.08	25.74	25.56	25.08	24.59	25.64	26.46	27.46
30	24.66	24.46	24.17	24.95	24.51	24.41	25.49	25.05	24.87	25.86	25.56	25.08	24.59	25.71	26.71	27.71
35	24.69	24.64	24.39	25.02	24.54	24.49	25.71	25.13	25.1	25.88	25.74	25.2	24.51	25.79	26.92	28.08
40	24.66	24.46	24.41	25	24.51	24.46	25.71	25.15	24.98	26.1	25.86	25.36	24.64	25.95	27.05	28.59
45	24.76	24.71	24.46	25.2	24.76	24.61	25.74	25.39	25.25	26.27	25.98	25.44	24.66	26.17	27.17	28.76
50	24.66	24.71	24.27	25.3	24.71	24.71	26.02	25.39	25.35	26.38	26.08	25.64	24.66	26.41	27.44	29.05
55	24.59	24.54	24.49	25.27	24.83	24.54	26.1	25.46	25.15	26.41	26.17	25.69	24.71	26.46	27.46	29.27
60	24.74	24.69	24.39	25.27	24.69	24.74	26.1	25.61	25.33	26.49	26.1	25.61	24.74	26.59	27.69	29.3
65	24.83	24.69	24.59	25.46	24.83	24.64	26.2	25.51	25.33	26.69	26.3	25.76	24.74	26.64	27.74	29.59
70	24.83	24.79	24.36	25.36	24.74	24.69	26.25	25.61	25.23	26.69	26.44	25.84	24.64	26.74	27.81	29.81
75	24.9	24.71	24.51	25.44	24.76	24.61	26.38	25.54	25.54	26.71	26.51	25.92	24.85	26.86	27.84	30.05
80	24.81	24.76	24.36	25.54	24.9	24.71	26.38	25.59	25.54	26.86	26.66	25.92	24.76	26.95	28.1	30.05
85	24.87	24.64	24.54	25.36	24.92	24.69	26.39	25.86	25.39	26.81	26.56	25.79	24.9	26.95	28	30.15
90	24.83	24.69	24.44	25.56	24.83	24.59	26.35	25.66	25.59	26.71	26.51	25.92	24.85	27	27.91	30.05
95	24.85	24.66	24.56	25.64	24.85	24.71	26.46	25.84	25.61	27.02	26.59	25.86	24.98	27.08	28.02	30.33
100	24.9	24.76	24.56	25.69	24.9	24.56	26.56	25.79	25.49	26.95	26.66	25.92	24.92	27.13	28.05	30.4
105	25	24.81	24.61	25.64	24.9	24.71	26.66	25.88	25.51	27.02	26.69	26.15	24.9	27.35	28.08	30.55
110	24.95	24.76	24.71	25.69	25	24.71	26.56	25.84	25.59	27.05	26.66	25.98	24.95	27.35	28.25	30.59
115	25	24.76	24.69	25.74	24.95	24.74	26.71	25.88	25.49	27.15	26.81	26.08	25.05	27.4	28.27	30.69
120	25	24.9	24.76	25.76	25	24.95	26.69	25.86	25.76	27.13	26.89	26.2	24.83	27.27	28.15	30.61

Table A2.6: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	24.9	24.9	24.71	25.81	24.81	24.81	26.79	26	25.84	27.05	26.86	26.08	25.1	27.44	28.3	30.69
130	25.02	24.87	24.69	25.79	24.98	24.83	26.66	25.84	25.59	27.2	26.86	26.23	24.9	27.54	28.17	30.69
135	25.02	24.83	24.79	25.81	24.87	24.92	26.84	25.86	25.71	27.13	26.84	26.39	25.17	27.37	28.3	30.91
140	25.08	24.85	24.81	25.61	25.08	24.9	26.84	25.9	25.74	27.35	26.86	26.17	25	27.54	28.4	30.96
145	25.1	24.9	24.85	25.88	25.1	24.95	26.71	25.98	25.66	27.23	26.92	26.35	25.13	27.71	28.48	31.04
150	25.13	25.02	24.69	25.81	25.17	25.08	26.79	25.95	25.86	27.33	26.98	26.1	25.08	27.61	28.33	30.99
155	25.02	24.98	24.83	25.84	25.1	24.92	26.66	26.08	25.79	27.2	26.91	26.27	24.85	27.64	28.48	31.1
160	25.15	24.9	24.69	25.92	25.05	24.95	26.61	25.84	25.84	27.25	26.86	26.23	25.05	27.79	28.4	30.96
165	24.98	24.87	24.87	25.92	25.17	25.08	26.81	26.08	25.76	27.33	26.98	26.2	25.02	27.66	28.42	31.08
170	25.23	24.98	24.79	25.81	25.08	24.87	26.84	26.1	25.79	27.27	26.89	26.46	24.98	27.76	28.4	31.01
175	25.13	24.92	24.92	25.76	25.23	24.98	26.89	26.05	25.86	27.27	26.92	26.39	25.13	27.61	28.42	31.17
180	24.98	25.02	24.79	25.86	25.13	24.98	26.89	26.15	25.69	27.4	27	26.17	24.95	27.69	28.45	31.2
185	25.08	25.08	24.85	25.76	25.13	24.85	26.79	26.05	25.76	27.23	26.92	26.2	25.08	27.71	28.56	31.12
190	25.17	25.02	24.83	25.79	25.23	25.02	26.89	26.02	25.71	27.42	26.98	26.49	24.98	27.71	28.48	31.23
195	24.92	24.87	24.87	25.98	25.17	25.08	26.86	26.12	25.86	27.37	26.92	26.35	25.13	27.86	28.51	31.23
200	24.95	24.95	24.76	25.84	25.2	25.05	26.91	26.08	25.88	27.35	26.86	26.27	24.9	27.89	28.45	31.33
205	25.08	24.79	24.74	26.05	25.08	24.87	26.84	26.2	25.74	27.4	26.95	26.33	25.05	27.84	28.45	31.1
210	25.08	24.98	24.83	25.86	25.08	24.92	26.84	26	25.95	27.33	26.98	26.25	24.98	27.86	28.48	31.04

Table A2.7: Experimental Data for Medium Sphere, $d_p = 3.87$ cm.
Run # 7: Re = 672.6 $Q_w = 79.4$ W/m^2 $T_{amb} = 24.0$ °C.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	23.17	23.13	23.02	23.17	23.13	23.36	23.31	23.36	23.71	23.66	23.61	23.46	22.83	23.71	23.8	23.9
5	23.13	23.17	23.17	23.13	23.05	23.23	23.31	23.36	23.56	23.71	23.71	23.51	23.31	23.9	24.1	24.34
10	23.2	23.2	23.1	23.44	23.15	23.29	23.69	23.49	23.59	23.95	23.9	23.69	23.49	24	24.64	24.79
15	23.41	23.26	23.23	23.66	23.26	23.26	24.02	23.76	23.76	24.46	24.23	23.8	23.46	24.17	25	25.66
20	23.51	23.26	23.31	23.8	23.31	23.26	24.3	23.85	23.85	24.49	24.44	24.05	23.61	24.39	25.54	26.25
25	23.61	23.56	23.46	23.95	23.46	23.41	24.54	24.1	23.9	24.87	24.59	24.1	23.66	24.39	25.69	26.59
30	23.46	23.61	23.23	23.9	23.66	23.41	24.69	24.34	23.9	25	24.66	24.3	23.66	24.76	26.15	27
35	23.76	23.56	23.46	24.2	23.66	23.46	24.87	24.2	24.1	25.27	25.02	24.44	23.66	24.92	26.51	27.54
40	23.74	23.54	23.44	24.36	23.69	23.59	25.15	24.48	24.1	25.36	25.02	24.64	23.71	25.23	26.79	27.84
45	23.8	23.51	23.31	24.39	23.56	23.46	25.13	24.44	24.15	25.49	25.25	24.64	23.61	25.15	26.89	28.25
50	23.74	23.64	23.44	24.46	23.64	23.44	25.35	24.56	24.36	25.54	25.44	24.81	23.69	25.39	27	28.61
55	23.61	23.61	23.26	24.44	23.8	23.61	25.27	24.64	24.36	25.69	25.39	24.85	23.79	25.44	27.1	28.81
60	23.88	23.59	23.49	24.66	23.69	23.64	25.44	24.56	24.51	25.79	25.64	24.81	23.69	25.64	27.3	28.96
65	23.74	23.69	23.69	24.61	23.83	23.54	25.49	24.61	24.36	25.98	25.64	24.9	23.74	25.84	27.4	29.38
70	23.79	23.64	23.49	24.61	23.98	23.64	25.79	24.85	24.46	25.98	25.69	24.81	23.83	25.84	27.49	29.48
75	23.9	23.56	23.34	24.59	23.8	23.56	25.66	24.79	24.46	26.15	25.88	24.81	23.69	26.1	27.44	29.66
80	23.92	23.79	23.54	24.61	23.88	23.69	25.84	24.71	24.61	26.15	25.76	25.02	23.88	26.2	27.61	29.89
85	23.76	23.66	23.46	24.71	23.76	23.8	25.84	24.9	24.54	26.08	25.92	25.25	23.85	26.27	27.84	29.91
90	23.95	23.76	23.51	24.79	23.9	23.71	25.86	24.98	24.54	26.41	25.98	25.25	23.74	26.46	27.61	30.05
95	23.95	23.8	23.61	24.79	23.85	23.61	25.76	24.92	24.74	26.41	26.02	25.1	23.59	26.51	27.79	30.05
100	23.92	23.74	23.54	24.64	23.92	23.59	25.86	24.87	24.59	26.46	25.92	25.1	23.61	26.41	27.79	30.15
105	23.83	23.79	23.59	24.9	23.83	23.64	25.98	25	24.69	26.33	26.23	25.36	23.85	26.56	27.86	30.4
110	23.98	23.79	23.49	24.76	23.92	23.64	25.98	24.92	24.76	26.41	26.08	25.44	23.74	26.61	27.94	30.52
115	23.88	23.79	23.59	24.83	24.02	23.69	26.02	25.08	24.66	26.46	26.02	25.35	23.98	26.66	28.02	30.52
120	23.79	23.69	23.64	24.76	23.98	23.59	25.88	25.1	24.74	26.49	26	25.33	23.76	26.81	27.95	30.64

Table A2.7: (Continue)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	23.95	23.76	23.51	24.87	23.85	23.61	26.15	24.92	24.59	26.61	26.23	25.27	23.95	26.71	28	30.66
130	24.02	23.79	23.64	24.95	24.02	23.79	26.02	25.25	24.61	26.64	26.2	25.46	23.9	26.84	28.15	30.89
135	23.95	23.76	23.61	24.98	24.05	23.76	26.2	25.27	24.85	26.64	26.27	25.44	23.88	26.98	28.27	30.89
140	24.02	23.83	23.69	25.15	24.08	23.88	26.23	25.15	24.9	26.79	26.3	25.59	23.88	26.98	28.17	31.04
145	23.98	23.76	23.8	25	23.98	23.66	26.12	25.1	24.76	26.92	26.33	25.49	23.83	27.08	28.27	31.12
150	24.13	23.74	23.61	25.05	24.08	23.83	26.17	25.1	24.87	26.71	26.38	25.66	24.1	27.1	28.38	31.1
155	24.13	23.88	23.79	25.05	24.08	23.83	26.3	25.13	24.81	26.79	26.49	25.56	23.9	27.08	28.35	31.08
160	24	23.95	23.76	25.1	24.23	23.95	26.27	25.2	24.83	26.84	26.35	25.51	24	27.05	28.35	31.2
165	24.23	24.02	23.92	25.17	24.34	24.02	26.35	25.36	24.98	26.92	26.54	25.56	24	27.25	28.35	31.17
170	24.31	24.17	23.92	25.35	24.36	23.98	26.41	25.44	25.08	26.98	26.54	25.76	24.1	27.35	28.49	31.4
175	24.2	24	23.76	25.36	24.15	23.95	26.39	25.27	24.95	26.89	26.59	25.54	24.02	27.27	28.42	31.33
180	24.25	24	23.8	25.05	24.25	23.95	26.33	25.44	24.95	26.98	26.38	25.54	24.02	27.33	28.51	31.52
185	24.25	24	23.69	25.23	24.2	24	26.35	25.27	25.1	26.95	26.66	25.69	24.08	27.37	28.38	31.42
190	24.17	24.05	23.76	25.25	24.27	24	26.41	25.44	24.95	26.92	26.76	25.59	23.98	27.33	28.51	31.48
195	24.17	24.13	23.88	25.33	24.31	24.02	26.46	25.36	25.05	27.13	26.59	25.79	24.13	27.59	28.59	31.33
200	24.3	23.9	23.8	25.17	24.39	24	26.54	25.36	25.1	27.08	26.74	25.88	24.08	27.51	28.51	31.69
205	24.23	24	24	25.3	24.23	24.05	26.61	25.59	25.02	27.05	26.59	25.86	24.05	27.59	28.74	31.66
210	24.2	23.95	23.85	25.23	24.25	24.1	26.54	25.36	25.08	27.1	26.81	25.71	23.9	27.44	28.59	31.71
215	24.27	24.08	23.92	25.23	24.36	24.17	26.49	25.46	25.1	27.13	26.81	25.84	24.02	27.71	28.56	31.69
220	24.34	24.1	23.85	25.25	24.3	24.1	26.56	25.3	25.13	27.15	26.79	25.95	24.1	27.69	28.69	31.71
225	24.27	24.17	23.79	25.35	24.36	24.13	26.56	25.49	25.15	27.08	26.74	25.59	24.02	27.61	28.61	31.89
230	24.34	24.05	23.95	25.33	24.25	24.15	26.54	25.71	25.08	27.1	26.71	25.71	24.3	27.59	28.64	31.71
235	24.34	24.05	24	25.36	24.25	24.05	26.54	25.56	25.2	27.23	26.81	25.98	24.23	27.66	28.61	31.89
240	24.36	24.17	23.9	25.39	24.31	24.02	26.66	25.54	25.17	27.25	26.71	25.71	24.2	27.71	28.76	31.84
245	24.25	24	24.05	25.36	24.3	24.25	26.69	25.51	25.02	27.3	26.86	25.81	24.25	27.81	28.76	31.71

Table A2.8: Experimental Data for Medium Sphere, $d_p = 3.87$ cm.
Run # 8: Re = 447.4 $Q_w = 79.4$ W/m^2 $T_{amb} = 23.5$ °C.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	21.92	22.13	22.13	22.17	22.27	22.63	22.42	22.63	22.92	23.02	23.08	23.02	21.63	23.61	22.77	23.36
5	21.98	22.02	22.17	22.08	22.23	22.48	22.48	22.52	22.9	23.05	23	22.95	22.4	23.56	23.26	23.8
10	22.27	22.42	22.42	22.83	22.37	22.63	23.08	22.88	23.08	23.41	23.41	23.36	22.73	23.71	23.9	24.54
15	22.58	22.58	22.52	22.77	22.48	22.73	23.31	23.13	23.29	23.64	23.74	23.44	22.88	23.79	24.51	25.23
20	23.13	22.77	22.73	23.26	22.83	22.98	23.9	23.46	23.46	24.13	24.13	23.36	23.23	23.98	25.25	25.86
25	23.1	22.8	22.8	23.64	22.95	22.95	24.27	23.59	23.66	24.44	24.2	23.9	23.56	24.34	25.74	26.54
30	23.34	22.95	23	23.98	23.25	23	24.56	23.83	23.76	24.74	24.59	24.05	23.41	24.49	26.49	27.17
35	23.26	23.17	22.92	24.2	23.23	23.02	24.92	23.85	23.98	25.05	24.76	24.23	23.44	24.66	26.76	27.76
40	23.51	23.36	23.13	24.39	23.46	23.08	25.13	24.2	23.98	25.35	25.15	24.27	23.54	24.81	27.25	28.23
45	23.64	23.39	23.1	24.51	23.54	23.25	25.44	24.27	24.1	25.69	25.35	24.46	23.51	25.2	27.4	28.81
50	23.74	23.29	23.29	24.81	23.69	23.34	25.79	24.46	24.25	25.92	25.64	24.69	23.61	25.49	27.84	29.33
55	23.79	23.39	23.25	24.81	23.74	23.29	25.92	24.56	24.34	26.12	25.79	24.83	23.76	25.64	28.1	29.74
60	23.74	23.49	23.44	25.2	23.92	23.39	26.02	24.76	24.39	26.38	25.98	25.02	23.71	25.88	28.35	30.04
65	23.8	23.51	23.34	24.98	24	23.51	26.1	24.79	24.61	26.49	26.05	25	23.92	26.15	28.56	30.48
70	23.88	23.59	23.39	25.39	23.98	23.44	26.51	24.95	24.61	26.81	26.25	25.23	23.88	26.2	28.69	30.74
75	23.76	23.56	23.46	25.08	24.1	23.41	26.54	24.98	24.74	26.76	26.33	25.46	23.9	26.38	28.84	31.06
80	24.13	23.64	23.44	25.56	24.31	23.69	26.71	25.02	24.74	27.05	26.56	25.46	23.74	26.61	29.15	31.3
85	23.83	23.64	23.39	25.39	24.13	23.79	26.76	25.25	24.76	27.15	26.64	25.64	23.79	26.79	29.23	31.6
90	23.98	23.66	23.46	25.59	24.08	23.79	26.98	25.2	24.87	27.27	26.69	25.64	23.8	26.92	29.2	31.74
95	24.05	23.61	23.41	25.61	24.2	23.76	26.92	25.23	24.95	27.3	26.81	25.66	23.69	27	29.38	32.13
100	24.02	23.79	23.39	25.74	24.23	23.74	27.05	25.25	25.02	27.42	26.86	25.81	23.85	26.95	29.45	32.09
105	24.15	23.71	23.51	25.59	24.15	23.85	27.17	25.35	24.92	27.46	26.95	25.9	23.9	27.27	29.64	32.35
110	24.02	23.83	23.54	25.81	24.31	23.79	27.25	25.41	25.05	27.66	27.05	25.81	23.88	27.35	29.84	32.5
115	24.15	23.74	23.59	25.71	24.34	23.88	27.17	25.51	25.13	27.76	27.17	25.98	23.8	27.61	29.71	32.63
120	24.05	23.8	23.46	25.84	24.39	23.71	27.27	25.35	25	27.84	27.13	26.12	23.8	27.54	29.89	32.79

Table A2.8: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	24	23.66	23.66	25.81	24.25	23.8	27.33	25.51	25.05	27.84	27.25	25.98	23.92	27.74	29.89	33.01
130	24.2	23.71	23.46	25.92	24.44	23.9	27.33	25.54	25.1	27.84	27.4	26.08	23.85	27.69	30.13	33.11
135	24.1	23.71	23.56	25.92	24.36	23.9	27.46	25.69	25.15	27.84	27.25	26.02	23.83	27.84	30.04	33.06
140	23.98	23.83	23.59	25.95	24.41	23.98	27.49	25.64	25.05	27.89	27.49	26.23	23.9	27.94	30.08	33.35
145	24.1	23.74	23.49	25.95	24.39	24.05	27.56	25.71	25.2	28.15	27.44	26.39	23.88	27.94	30.13	33.35
150	24.13	23.74	23.49	26.05	24.39	24.02	27.56	25.61	25.23	28.13	27.51	26.33	23.95	28.08	30.27	33.4
155	24.13	23.83	23.54	26.05	24.51	24.08	27.69	25.56	25.3	28.1	27.64	26.2	23.88	28.2	30.23	33.38
160	24.15	23.71	23.51	26.02	24.49	23.8	27.66	25.74	25.23	28.17	27.46	26.41	23.8	28.23	30.3	33.69
165	24.17	23.74	23.54	26	24.49	24.02	27.76	25.81	25.33	28.1	27.56	26.35	23.9	28.27	30.15	33.69
170	24.08	23.74	23.56	26.15	24.61	23.98	27.69	25.71	25.35	28.3	27.54	26.44	23.92	28.45	30.35	33.74
175	24.15	23.66	23.46	26.08	24.61	24.05	27.64	25.79	25.33	28.15	27.66	26.39	23.74	28.48	30.35	33.79
180	24.05	23.74	23.59	26.23	24.59	24.15	27.56	25.79	25.23	28.33	27.56	26.38	23.85	28.42	30.38	33.81
185	24.02	23.74	23.44	26.15	24.51	24.02	27.74	25.81	25.23	28.23	27.71	26.38	23.9	28.61	30.3	33.79
190	24.36	23.83	23.74	26.35	24.66	24.02	27.79	25.66	25.44	28.42	27.61	26.51	23.9	28.59	30.38	33.86
195	24.23	23.88	23.66	26.15	24.61	24.13	27.84	25.9	25.39	28.4	27.74	26.54	24.02	28.64	30.38	33.99
200	24.17	23.98	23.69	26.3	24.66	24.08	28.02	25.81	25.39	28.45	27.79	26.54	23.92	28.74	30.38	34.01
205	24.27	23.92	23.64	26.2	24.61	24.02	27.86	25.81	25.33	28.42	27.71	26.56	24.2	28.76	30.5	34.11
210	24.3	24.08	23.83	26.35	24.79	24.23	28	25.86	25.64	28.48	27.84	26.64	24.13	28.74	30.66	34.2
215	24.41	24.08	23.79	26.44	24.76	24.23	28.02	25.86	25.39	28.59	27.89	26.64	24.08	28.79	30.79	34.28
220	24.39	24.05	23.83	26.41	24.87	24.2	28.05	25.9	25.69	28.61	27.86	26.89	24.27	28.71	30.61	34.14
225	24.56	24.1	23.95	26.56	24.85	24.15	28.17	26.02	25.51	28.56	28	26.66	24.25	29.05	30.74	34.4
230	24.49	24.2	23.79	26.56	24.92	24.34	28.05	26.02	25.59	28.61	27.91	26.91	24.13	28.94	30.81	34.53
235	24.49	24.17	23.83	26.54	24.79	24.2	28.2	26	25.71	28.54	28.15	26.84	24.1	29.05	30.74	34.42
240	24.44	24.2	23.92	26.56	24.98	24.44	28.1	26.08	25.56	28.76	28	26.86	23.95	28.91	30.84	34.5
245	24.56	24.17	23.9	26.49	24.85	24.23	28.27	26.12	25.64	28.84	28.08	26.92	24.27	29.08	30.86	34.58
250	24.39	24.17	23.98	26.69	24.98	24.31	28.3	26.15	25.74	28.86	28.17	26.86	24.17	29.17	31.01	34.58
255	24.56	24.1	23.85	26.66	24.95	24.25	28.27	26.17	25.59	28.84	28.13	26.79	24.13	29.13	30.91	34.67
260	24.46	24.02	23.88	26.64	24.92	24.36	28.3	26.1	25.71	28.86	28.3	26.86	24.15	29.15	30.99	34.76
265	24.49	24.15	23.9	26.51	24.83	24.44	28.25	26.08	25.81	29	28.15	26.95	24.05	29.2	30.94	34.7

Table A2.9: Experimental Data for Medium Sphere, $d_p = 3.87$ cm.
Run # 9: Re = 1065.9 $Q_w = 19.8\ W/m^2$ $T_{amb} = 24.5$ °C.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	$T_w 1$	$T_w 2$
0	23.39	23.39	23.44	23.64	23.59	23.74	23.74	24.02	24.17	24.17	24.23	24.27	23.29	24.46	24.13	24.51
5	23.54	23.64	23.59	23.59	23.69	23.83	23.79	23.83	24.02	24.13	24.17	24.27	23.79	24.36	24.02	24.51
10	23.76	23.66	23.66	23.66	23.76	23.71	23.8	23.85	24.15	24.2	24.15	24.05	23.85	24.34	24.1	24.59
15	23.98	23.83	23.79	23.88	23.74	23.74	24.13	23.98	24.15	24.39	24.25	24.34	24	24.44	24.44	24.64
20	24.02	23.79	23.79	23.92	23.74	23.88	24.02	23.88	24.27	24.27	24.27	24.23	24.23	24.31	24.51	24.66
25	23.92	23.98	24.02	24.08	23.92	24.08	24.23	24.08	24.3	24.59	24.39	24.44	24.1	24.54	24.64	24.83
30	24.23	24.13	24.08	24.17	24.08	23.98	24.27	24.23	24.31	24.61	24.46	24.23	24.41	24.56	24.76	24.95
35	24.15	24.2	24	24.44	24.15	24.05	24.34	24.3	24.36	24.56	24.61	24.27	24.31	24.56	24.9	25.2
40	24.23	24.23	24.13	24.27	24.17	24.13	24.46	24.27	24.49	24.74	24.64	24.44	24.64	24.59	24.92	25.17
45	24.27	24.31	24.17	24.36	24.17	24.17	24.36	24.36	24.41	24.76	24.81	24.56	24.41	24.76	25.17	25.27
50	24.41	24.27	24.13	24.36	24.13	24.08	24.51	24.46	24.51	24.66	24.76	24.36	24.51	24.71	24.95	25.2
55	24.34	24.3	24.25	24.39	24.25	24.15	24.59	24.34	24.66	24.71	24.71	24.46	24.61	24.76	24.95	25.44
60	24.36	24.27	24.23	24.46	24.17	24.27	24.51	24.31	24.56	24.9	24.71	24.56	24.31	24.85	24.95	25.51
65	24.44	24.2	24.3	24.44	24.25	24.2	24.59	24.54	24.61	24.95	24.76	24.41	24.61	24.85	25.1	25.49
70	24.49	24.39	24.2	24.34	24.3	24.25	24.74	24.54	24.69	24.92	24.83	24.54	24.49	24.87	25.08	25.64
75	24.34	24.44	24.2	24.34	24.25	24.3	24.71	24.49	24.56	24.85	24.9	24.76	24.66	24.81	25.2	25.51
80	24.54	24.39	24.3	24.34	24.39	24.3	24.49	24.59	24.79	24.92	24.87	24.59	24.59	24.92	25.17	25.46
85	24.46	24.51	24.36	24.41	24.41	24.36	24.81	24.76	24.66	25.05	24.95	24.56	24.46	25.05	25.25	25.66
90	24.39	24.39	24.44	24.54	24.34	24.49	24.83	24.64	24.76	25.2	25.05	24.76	24.81	25.1	25.3	25.74
95	24.51	24.56	24.41	24.56	24.36	24.51	24.9	24.71	24.71	25.1	25	24.81	24.71	25	25.3	25.66
100	24.56	24.61	24.41	24.51	24.46	24.41	24.81	24.66	24.76	25.1	25	24.81	24.71	24.95	25.39	25.92
105	24.71	24.56	24.46	24.56	24.56	24.61	24.9	24.85	24.9	25.2	25	24.85	24.81	25.05	25.44	25.92
110	24.59	24.54	24.3	24.64	24.54	24.54	24.83	24.79	24.83	24.98	24.98	24.74	24.83	24.83	25.36	26
115	24.64	24.54	24.49	24.54	24.59	24.54	24.87	24.69	24.76	24.9	25.1	24.85	25	25.05	25.39	25.84
120	24.69	24.49	24.39	24.64	24.64	24.59	24.92	24.74	24.95	25.13	25.05	24.95	24.76	25.17	25.46	25.81

Table A2.9: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	24.66	24.71	24.51	24.61	24.51	24.51	24.95	24.95	24.9	25.15	25	24.81	24.76	25.1	25.39	26.15
130	24.66	24.66	24.61	24.76	24.71	24.56	24.95	24.95	24.92	25.13	25.17	25.17	24.79	25.08	25.51	25.9
135	24.76	24.66	24.61	24.81	24.61	24.61	24.9	24.81	25	25.2	25.25	24.95	24.85	25.2	25.44	25.92
140	24.76	24.9	24.46	24.66	24.61	24.56	25.05	24.95	25	25.3	25.15	24.95	24.95	25.15	25.56	25.95
145	24.9	24.71	24.56	24.81	24.66	24.61	25	25	25.05	25.3	25.2	25	24.95	25.25	25.59	26.02
150	24.81	24.61	24.61	24.81	24.61	24.66	25	24.95	25	25.3	25.15	24.85	24.81	25.3	25.54	26.02
155	24.81	24.71	24.51	24.85	24.71	24.76	25.05	24.95	25.05	25.49	25.2	25	24.95	25.25	25.44	26.08
160	24.9	24.76	24.56	24.95	24.71	24.66	25	24.85	25.1	25.39	25.35	24.95	24.85	25.25	25.39	25.98
165	24.87	24.79	24.69	24.98	24.83	24.74	25.08	25.08	25.02	25.46	25.27	25.17	24.87	25.33	25.71	26.15
170	24.81	24.9	24.76	25	24.81	24.66	25.1	25.05	25.02	25.46	25.27	25.08	24.87	25.41	25.69	26.33
175	24.92	24.87	24.74	24.92	24.79	24.87	25.17	25.08	25.2	25.35	25.35	25.05	25.05	25.35	25.71	26.2
180	24.98	24.87	24.92	24.98	24.98	24.79	25.27	25.17	25.15	25.39	25.3	25.05	25.05	25.35	25.74	26.27
185	25.08	24.87	24.92	24.98	24.74	24.83	25.23	25.08	25.1	25.44	25.35	25.15	25.15	25.25	25.74	26.23
190	25	25	24.76	25	24.9	24.81	25.25	25.15	25.17	25.56	25.36	25.27	25.17	25.36	25.81	26.3
195	25.02	24.87	24.69	25.08	24.79	24.87	25.33	25.17	25.27	25.51	25.46	25.08	25.13	25.36	25.81	26.2
200	25.1	24.9	24.76	25.15	24.85	24.85	25.35	25.3	25.27	25.41	25.41	25.33	25.02	25.46	25.86	26.3
205	25.15	25.1	24.9	25	24.95	24.85	25.2	25.15	25.27	25.61	25.51	25.27	25.23	25.51	25.9	26.25
210	25.08	25.13	24.79	25.08	24.87	24.92	25.33	25.23	25.36	25.56	25.41	25.23	25.08	25.71	25.76	26.35
215	24.98	25.02	24.98	25.08	24.87	24.79	25.33	25.23	25.27	25.61	25.46	25.27	25.23	25.66	25.76	26.41
220	25.13	25.17	24.92	25.23	24.92	24.98	25.41	25.17	25.33	25.61	25.46	25.41	25.13	25.61	25.95	26.35
225	25.13	25.23	25.02	25.02	25.02	25.08	25.36	25.27	25.36	25.56	25.61	25.51	25.08	25.61	25.9	26.49
230	25.15	25.05	25.05	25.1	24.9	24.85	25.3	25.35	25.39	25.69	25.54	25.54	25.1	25.74	25.84	26.46
235	25.05	25.05	24.95	25.05	25	24.95	25.49	25.2	25.41	25.66	25.56	25.23	25.13	25.56	25.9	26.49
240	25.05	25.2	24.9	25	25	25.05	25.3	25.35	25.35	25.69	25.49	25.44	25.25	25.59	25.98	26.38
245	24.98	25.02	24.98	25.17	24.98	24.98	25.27	25.23	25.39	25.64	25.49	25.44	25.15	25.49	25.88	26.49
250	25.05	25.25	24.95	25.1	24.95	25	25.3	25.35	25.49	25.64	25.64	25.35	25.15	25.54	25.84	26.46
255	25.15	24.95	25.05	25	25.05	25	25.39	25.35	25.46	25.71	25.61	25.36	25.33	25.56	25.95	26.49

Table A2.10: Experimental Data for Medium Sphere, $d_p = 3.87$ cm.
Run # 10: Re = 880.6 $Q_w = 19.8$ W/m^2 $T_{amb} = 24.8$ °C.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	22.52	22.73	22.83	22.67	22.98	23.26	22.98	23.17	23.59	23.49	23.69	23.83	22.95	24.27	23.2	23.92
5	22.85	23.05	23.15	22.95	23	23.25	23.15	23.44	23.88	23.54	23.74	23.69	23.59	24.23	23.49	24.08
10	23.39	23.59	23.25	23.29	23.25	23.49	23.44	23.49	23.8	23.8	23.9	23.76	23.8	24.25	23.85	24.1
15	23.69	23.49	23.54	23.54	23.49	23.54	23.69	23.74	23.85	23.95	24	24	24.05	24.15	24.05	24.34
20	23.9	23.66	23.76	23.76	23.71	23.71	24	23.85	23.98	24.13	24.17	24.02	24.36	24.27	24.27	24.56
25	24.02	23.92	23.88	23.88	23.83	23.79	23.98	23.98	24.02	24.23	24.23	24.08	24.17	24.36	24.41	24.71
30	24.1	24.05	23.9	24.05	23.9	23.9	24.15	24.15	24.27	24.36	24.36	24.27	24.23	24.36	24.61	24.95
35	24.17	24.23	23.98	24.23	24.02	24.02	24.27	24.27	24.23	24.61	24.51	24.17	24.51	24.56	24.85	25.1
40	24.25	24.25	24.1	24.3	24.1	24.05	24.49	24.39	24.41	24.66	24.66	24.31	24.46	24.66	24.85	25.2
45	24.46	24.23	23.98	24.27	24.17	24.13	24.51	24.27	24.46	24.71	24.66	24.51	24.56	24.66	25	25.35
50	24.51	24.46	24.23	24.36	24.17	24.17	24.61	24.36	24.51	24.71	24.71	24.46	24.66	24.76	25.15	25.49
55	24.44	24.44	24.2	24.44	24.2	24.15	24.54	24.64	24.54	24.87	24.79	24.69	24.74	24.83	25.17	25.54
60	24.49	24.44	24.3	24.44	24.15	24.2	24.69	24.59	24.66	24.76	24.85	24.51	24.51	24.81	25.25	25.54
65	24.3	24.3	24.3	24.39	24.25	24.2	24.69	24.44	24.66	24.95	24.95	24.46	24.51	24.9	25.3	25.64
70	24.44	24.44	24.34	24.49	24.34	24.25	24.64	24.69	24.71	25.1	24.9	24.56	24.56	24.85	25.3	25.74
75	24.61	24.56	24.41	24.56	24.36	24.36	24.76	24.71	24.69	25.08	24.98	24.74	24.59	24.98	25.46	25.81
80	24.56	24.56	24.36	24.51	24.46	24.41	24.81	24.66	24.74	25.17	25.02	24.83	24.59	25.02	25.33	26
85	24.44	24.54	24.39	24.49	24.34	24.3	24.92	24.69	24.76	25.15	25	24.85	24.56	25.15	25.54	25.92
90	24.51	24.36	24.17	24.51	24.31	24.27	24.66	24.56	24.66	25.15	25	24.81	24.51	25.1	25.39	25.98
95	24.36	24.46	24.46	24.56	24.46	24.46	24.9	24.81	24.83	25.02	25.13	24.59	24.39	25.08	25.33	25.9
100	24.51	24.41	24.27	24.46	24.36	24.36	24.9	24.71	24.95	25.1	25	24.81	24.51	25.05	25.35	25.92
105	24.56	24.36	24.31	24.46	24.31	24.41	24.95	24.76	24.79	25.08	25.02	24.83	24.59	25.17	25.41	25.95
110	24.51	24.41	24.41	24.56	24.23	24.36	24.83	24.74	24.87	25.17	25.08	24.59	24.59	25.23	25.46	26
115	24.44	24.44	24.3	24.54	24.39	24.34	24.74	24.69	24.81	25.1	24.95	24.85	24.51	25.05	25.35	26.08
120	24.34	24.39	24.34	24.64	24.39	24.34	24.79	24.64	24.83	25.13	25.02	24.69	24.59	25.08	25.33	25.95

Table A2.11: Experimental Data for Medium Sphere, $d_p = 3.87$ cm.
Run # 11: Re = 672.6 $Q_w = 19.8\ W/m^2$ $T_{amb} = 25.2\ ^{\circ}C$.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	23.74	23.98	23.92	24.1	24.15	24.25	24.25	24.25	24.66	24.56	24.76	24.76	23.49	24.81	24.61	24.9
5	23.88	24.02	24.02	23.88	23.92	24.27	24.27	24.27	24.49	24.64	24.64	24.49	24.05	24.83	24.79	24.98
10	23.95	23.85	23.95	24	24	24.17	24.23	24.23	24.56	24.56	24.61	24.51	24.23	24.76	24.66	25.08
15	24.23	24.13	24.17	24.02	24.13	24.27	24.41	24.36	24.61	24.71	24.66	24.61	24.56	24.85	24.81	24.95
20	24.13	24.27	24.08	24.17	24.13	24.17	24.36	24.41	24.59	24.74	24.59	24.59	24.49	24.87	24.79	25.33
25	24.3	24.39	24.34	24.39	24.2	24.3	24.59	24.44	24.61	24.95	24.81	24.66	24.56	25	25.05	25.25
30	24.41	24.27	24.23	24.41	24.23	24.23	24.61	24.56	24.71	24.85	24.81	24.61	24.56	24.85	25.05	25.49
35	24.59	24.39	24.25	24.39	24.3	24.25	24.69	24.54	24.76	24.95	24.85	24.81	24.66	24.9	25.15	25.64
40	24.46	24.51	24.31	24.56	24.23	24.36	24.66	24.61	24.79	24.98	24.98	24.79	24.69	25.02	25.33	25.76
45	24.69	24.54	24.49	24.64	24.44	24.49	24.87	24.74	24.74	25.13	24.98	24.79	24.87	25.08	25.33	25.81
50	24.66	24.51	24.36	24.56	24.31	24.36	24.71	24.76	24.83	25.17	25.02	24.87	24.69	25.13	25.46	25.9
55	24.61	24.66	24.41	24.71	24.46	24.46	24.98	24.83	24.87	25.17	25.08	24.83	24.83	25.17	25.64	26.08
60	24.61	24.51	24.41	24.56	24.46	24.41	24.9	24.81	24.87	25.33	25.13	24.87	24.74	25.23	25.56	26.02
65	24.69	24.69	24.39	24.71	24.34	24.49	25.05	24.81	24.81	25.3	25.25	24.95	24.66	25.2	25.64	26.2
70	24.56	24.61	24.41	24.66	24.41	24.41	25.1	24.85	24.92	25.36	25.13	24.83	24.74	25.36	25.56	26.15
75	24.64	24.64	24.54	24.69	24.59	24.44	25.05	25	24.85	25.3	25.2	24.81	24.61	25.2	25.69	26.33
80	24.66	24.61	24.51	24.61	24.46	24.41	25.05	25.05	24.98	25.36	25.27	24.98	24.64	25.27	25.76	26.1
85	24.66	24.61	24.39	24.66	24.51	24.39	25	24.81	25.05	25.35	25.35	24.95	24.66	25.15	25.64	26.33
90	24.66	24.61	24.51	24.76	24.56	24.61	25	25.05	24.98	25.33	25.23	24.98	24.74	25.23	25.71	26.2
95	24.81	24.66	24.51	24.71	24.46	24.56	25.1	25.05	25.02	25.46	25.41	25.02	24.87	25.36	25.66	26.49
100	24.81	24.51	24.56	24.71	24.41	24.56	25.05	24.85	25.08	25.36	25.17	25.08	24.59	25.46	25.76	26.39
105	24.76	24.66	24.56	24.71	24.66	24.56	25.25	24.95	25	25.39	25.35	25.2	24.71	25.39	25.79	26.51
110	24.76	24.66	24.59	24.81	24.66	24.59	25.15	25.1	25.05	25.44	25.35	25.25	24.76	25.54	25.79	26.33
115	24.69	24.59	24.64	24.74	24.49	24.54	25.13	25.13	25.02	25.46	25.46	24.92	24.59	25.33	25.9	26.44
120	24.64	24.54	24.54	24.69	24.59	24.69	25.08	25.13	25.1	25.69	25.25	25.15	24.81	25.39	25.92	26.51

Table A2.11: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	24.81	24.56	24.61	24.71	24.56	24.56	25.2	25	24.95	25.44	25.44	25.15	24.56	25.54	25.79	26.51
130	24.83	24.64	24.46	24.92	24.51	24.69	25.17	25.27	25.17	25.41	25.33	25.08	24.87	25.46	25.9	26.49
135	24.79	24.64	24.54	24.79	24.59	24.69	25.13	24.92	25.17	25.61	25.36	25.13	24.87	25.56	25.81	26.59
140	24.74	24.64	24.59	24.74	24.54	24.64	25.25	25	25.13	25.56	25.41	24.98	24.81	25.46	25.86	26.51
145	24.79	24.69	24.64	24.83	24.49	24.69	25.17	25.02	25.05	25.59	25.39	25.25	24.85	25.74	25.88	26.46
150	24.79	24.59	24.54	24.92	24.64	24.64	25.17	25.02	24.92	25.51	25.33	25.23	24.83	25.51	25.86	26.49
155	24.76	24.76	24.61	24.79	24.66	24.66	25.33	25.23	25.2	25.59	25.49	25.2	25	25.59	25.98	26.66
160	24.85	24.66	24.61	24.81	24.66	24.61	25.25	25.2	25.1	25.64	25.44	24.95	24.76	25.54	25.98	26.71
165	24.81	24.61	24.61	24.81	24.66	24.56	25.23	25.1	25.17	25.66	25.51	25.13	24.79	25.61	26	26.74
170	24.76	24.81	24.61	24.9	24.66	24.71	25.2	25.2	25.13	25.56	25.51	25.41	24.87	25.66	26	26.64

Table A2.12: Experimental Data for Medium Sphere, $d_p = 3.87$ cm.
Run # 12: Re = 447.4 $Q_w = 19.8$ W/m^2 $T_{amb} = 24.6$ °C.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	23.39	23.64	23.39	23.64	23.79	23.98	23.98	23.98	24.39	24.44	24.44	24.44	22.42	24.79	24.34	24.54
5	23.08	23.31	23.31	23.26	23.26	23.66	23.66	23.85	24.2	24.34	24.3	24.44	23.1	24.64	24.15	24.69
10	23.34	23.34	23.39	23.44	23.44	23.79	23.83	23.88	24.23	24.27	24.27	24.31	23.39	24.61	24.36	24.85
15	23.34	23.34	23.25	23.44	23.59	23.69	23.98	23.88	24.13	24.27	24.36	24.13	23.44	24.56	24.27	24.9
20	23.61	23.46	23.46	23.61	23.61	23.8	24.05	23.95	24.27	24.46	24.36	24.27	23.64	24.74	24.41	25.13
25	23.54	23.54	23.44	23.59	23.54	23.83	24.02	23.92	24.15	24.41	24.51	24.25	23.8	24.71	24.56	25.15
30	23.71	23.71	23.61	23.71	23.66	23.76	24.2	24	24.36	24.56	24.51	24.23	23.88	24.66	24.85	25.25
35	23.71	23.61	23.61	23.8	23.66	23.76	24.15	23.95	24.3	24.54	24.76	24.25	23.8	24.69	24.85	25.35
40	23.69	23.69	23.74	23.92	23.64	23.79	24.31	24.17	24.23	24.51	24.51	24.36	23.92	24.66	24.95	25.44
45	23.8	23.85	23.56	23.95	23.8	23.8	24.25	24.25	24.39	24.59	24.79	24.34	24	24.87	25.13	25.71
50	24.05	23.8	23.8	24.05	23.8	23.8	24.41	24.3	24.34	24.74	24.83	24.3	24.05	24.79	25.02	25.76
55	23.92	23.8	23.8	24.02	23.85	23.8	24.51	24.27	24.36	24.76	24.81	24.61	23.98	24.81	25.25	25.86
60	23.9	23.8	23.64	24.05	23.8	23.79	24.49	24.2	24.36	24.81	24.76	24.46	24.02	24.92	25.27	25.86
65	23.8	23.85	23.85	24.1	23.9	23.8	24.54	24.2	24.44	24.98	24.79	24.39	23.95	25.02	25.3	25.92
70	23.88	23.88	23.74	24.23	23.79	23.79	24.51	24.36	24.44	24.92	24.79	24.49	23.8	24.98	25.35	25.98
75	23.95	23.76	23.71	24.2	23.85	23.95	24.69	24.25	24.44	25.02	24.87	24.54	23.95	24.98	25.36	26.08
80	23.92	23.83	23.69	24.23	23.79	23.88	24.54	24.3	24.36	25.05	24.95	24.46	23.92	25.05	25.44	26.17
85	23.92	23.92	23.79	24.31	23.92	23.83	24.66	24.41	24.44	24.87	24.92	24.64	24.05	24.98	25.51	26.1
90	23.9	23.9	23.8	24.3	23.95	23.85	24.64	24.44	24.54	24.98	24.87	24.49	24	25.08	25.41	26.25
95	23.92	24	23.83	24.25	23.95	23.88	24.54	24.34	24.31	25.05	24.85	24.51	24.17	25.15	25.39	26.15
100	24.1	24	24	24.3	23.9	24.05	24.79	24.49	24.49	25.02	24.83	24.59	24.1	24.98	25.56	26.27
105	23.95	23.9	23.9	24.25	23.95	23.9	24.83	24.49	24.46	25.1	24.95	24.66	24.13	25.2	25.54	26.3
110	24.2	24.05	23.9	24.34	24.25	24.1	24.87	24.54	24.51	25.05	25	24.85	24.23	25.15	25.66	26.35
115	24.15	23.9	23.95	24.34	24.1	24	24.87	24.59	24.61	25.1	25	24.81	24.31	25.35	25.69	26.64
120	24.23	23.92	23.92	24.36	24.08	24.02	24.81	24.61	24.56	25.15	25.1	24.85	24.17	25.25	25.59	26.46

Table A2.12: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	24.23	24.08	23.98	24.36	24.17	24.08	24.83	24.49	24.64	25.23	25.02	24.83	24.25	25.33	25.76	26.35
130	24.3	24.08	23.83	24.49	24.13	24.08	24.79	24.59	24.61	25.2	25.1	24.71	24.23	25.1	25.66	26.64
135	24.23	23.98	24.08	24.64	24.27	24.08	24.92	24.54	24.51	25.25	25.2	24.66	24.36	25.3	25.88	26.61
140	24.15	24.05	23.85	24.49	24.05	24.2	24.98	24.64	24.59	25.17	25.08	24.79	24.44	25.23	25.79	26.61
145	24.3	24.05	23.9	24.49	24.2	23.95	25.02	24.59	24.71	25.2	25.15	24.76	24.51	25.3	25.81	26.49
150	24.44	24.15	24.05	24.59	24.3	24.1	25	24.69	24.74	25.33	25.27	24.83	24.39	25.27	25.76	26.61
155	24.39	24.3	24.15	24.81	24.34	24.15	24.95	24.64	24.81	25.39	25.05	24.85	24.41	25.35	25.98	26.59
160	24.39	24.25	24.1	24.59	24.2	24.2	25.05	24.71	24.74	25.41	25.23	24.87	24.49	25.27	25.81	26.81
165	24.44	24.25	24.13	24.79	24.3	24.13	25.02	24.64	24.74	25.41	25.17	25.08	24.64	25.41	26	26.81
170	24.59	24.34	24.25	24.54	24.34	24.15	25.1	24.79	24.87	25.41	25.41	25.08	24.69	25.51	26	26.92
175	24.51	24.34	24.3	24.76	24.44	24.25	25.25	24.81	24.76	25.39	25.25	24.9	24.56	25.39	25.98	26.84
180	24.51	24.31	24.23	24.66	24.51	24.23	25.25	24.85	24.79	25.56	25.36	24.87	24.54	25.41	26	26.76
185	24.54	24.49	24.44	24.69	24.39	24.34	25.27	24.92	24.95	25.44	25.35	24.95	24.71	25.54	26.12	26.91
190	24.64	24.44	24.3	24.79	24.54	24.44	25.23	24.83	24.92	25.59	25.39	25.17	24.83	25.59	26.17	26.95
195	24.59	24.44	24.34	24.98	24.54	24.44	25.39	24.87	25	25.54	25.3	25.1	24.66	25.64	26.02	26.89
200	24.46	24.51	24.31	24.81	24.51	24.41	25.35	24.81	24.87	25.71	25.51	25.02	24.74	25.56	26.3	26.89
205	24.71	24.61	24.51	25	24.56	24.36	25.3	25.05	24.98	25.76	25.41	25.17	24.79	25.56	26.3	26.95
210	24.71	24.54	24.44	24.95	24.59	24.44	25.25	24.95	24.98	25.76	25.36	25.13	24.64	25.76	26.2	27.2
215	24.69	24.56	24.41	25.08	24.74	24.41	25.46	25.08	24.85	25.69	25.49	25.15	24.9	25.74	26.38	27.02
220	24.64	24.49	24.49	24.98	24.54	24.49	25.41	25.08	25.1	25.79	25.54	25.35	24.95	25.74	26.33	27.1
225	24.56	24.56	24.41	25.1	24.61	24.46	25.51	25	25.13	25.81	25.46	24.98	24.74	25.76	26.3	27.3
230	24.69	24.64	24.49	25.02	24.59	24.49	25.49	25.13	24.98	25.86	25.66	25.27	24.69	25.76	26.39	27.17
235	24.71	24.49	24.44	24.95	24.59	24.54	25.49	25.05	24.98	25.86	25.56	25.27	24.87	25.71	26.25	27.2

Table A3.1: Experimental Data for Large Sphere, $d_p = 5.25$ cm.
Run # 1: Re = 1538.8 $Q_w = 243.4$ W/m^2 $T_{amb} = 25.2$ °C.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	24.56	24.56	24.61	24.46	24.51	24.46	24.61	24.56	25	25.05	25	24.85	24.66	25.05	25.05	25.05
5	24.92	24.69	24.64	24.79	24.69	24.69	24.98	24.92	25.02	25.33	25.13	25.08	24.87	25.36	26.61	26.56
10	24.83	24.83	24.54	25.13	24.64	24.64	25.46	25.17	25.08	25.9	25.27	24.98	24.59	25.81	28	28.05
15	25.13	25.02	24.69	25.27	24.83	24.74	25.81	25.46	25.39	26.38	25.79	25.25	24.71	26.23	29.23	29.54
20	25.1	24.81	24.81	25.35	24.85	24.81	26.2	25.69	25.39	26.76	26.08	25.39	24.83	26.56	30.45	30.55
25	25.23	24.92	24.87	25.56	25.08	24.87	26.35	25.9	25.59	27.27	26.46	25.69	25.1	27.17	31.25	31.79
30	25.27	25.13	24.64	25.61	25.08	24.87	26.54	25.95	25.71	27.54	26.56	25.81	24.98	27.59	31.91	32.64
35	25.27	24.98	24.87	25.71	25.08	24.98	26.81	26.15	25.76	27.89	26.84	26.05	25.08	27.98	32.55	33.33
40	25.41	25.17	24.74	25.86	25.17	24.98	26.92	26.2	25.9	28.17	27.15	25.95	24.87	28.02	33.09	34.06
45	25.39	25.2	24.81	25.84	25.15	25.15	27.08	26.41	25.86	28.48	27.27	26	25.08	28.38	33.58	34.63
50	25.49	25.25	25	25.98	25.2	25.2	27.05	26.46	25.9	28.61	27.46	26.15	24.83	28.76	34.04	35.3
55	25.49	25.17	25.05	26.02	25.23	25.15	27.05	26.51	25.92	28.69	27.44	26.17	24.95	28.74	34.2	35.3
60	25.46	25.33	25.13	25.95	25.23	25.17	27.25	26.56	25.95	28.86	27.51	26.3	25.27	28.91	34.33	35.8
65	25.59	25.39	25	26.12	25.3	25.15	27.44	26.71	26.02	29	27.61	26.38	24.98	29.25	34.67	36.21
70	25.56	25.27	24.87	26.15	25.33	25.23	27.27	26.69	26.27	29.08	27.69	26.46	25	29.38	34.76	36.45
75	25.41	25.33	25.02	26.15	25.33	25.27	27.54	26.89	26.02	29.23	27.79	26.51	25.25	29.42	35.28	36.97
80	25.51	25.23	24.92	26.25	25.46	25.13	27.51	26.92	26.23	29.33	27.98	26.56	24.74	29.59	35.24	37
85	25.54	25.15	24.85	26.08	25.2	25.25	27.3	26.91	26.15	29.25	27.86	26.49	24.98	29.66	35.35	37.11
90	25.56	25.08	24.95	26.1	25.23	25.27	27.59	26.95	26.15	29.4	27.86	26.64	25.13	29.86	35.72	37.31
95	25.41	25.17	24.87	26.25	25.33	25.17	27.59	26.84	26.15	29.4	28.2	26.59	25.08	29.74	35.67	37.44
100	25.61	25.17	25.02	26.2	25.36	25.33	27.79	27.13	26.17	29.48	28.08	26.46	25.1	30.04	35.86	37.56
105	25.61	25.33	25.08	26.25	25.41	25.27	27.74	27.08	26.12	29.61	28.02	26.56	25	30.04	36.06	37.92
110	25.64	25.3	25.02	26.33	25.39	25.17	27.86	27.08	26.17	29.69	28.1	26.61	25.35	30.23	36.06	38.05
115	25.69	25.44	25.05	26.51	25.39	25.25	27.94	27.1	26.35	29.86	28.15	26.89	25.33	30.3	36.41	38.22
120	25.49	25.3	25.1	26.27	25.54	25.3	27.86	27.13	26.2	29.86	28.42	26.84	25.25	30.38	36.36	38.3

Table A3.1: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	25.71	25.49	25.05	26.33	25.59	25.39	27.84	27.15	26.38	29.84	28.25	26.95	24.92	30.33	36.39	38.49
130	25.61	25.36	25.08	26.39	25.56	25.41	27.94	27.17	26.27	29.94	28.4	26.95	25.08	30.4	36.39	38.41
135	25.69	25.44	25	26.38	25.39	25.25	28.08	27.15	26.39	29.91	28.48	26.79	25.05	30.61	36.5	38.61
140	25.69	25.39	25	26.38	25.44	25.15	27.91	27.2	26.49	29.84	28.49	26.98	25.36	30.45	36.55	38.71
145	25.66	25.33	25.13	26.39	25.66	25.41	28.13	27.25	26.35	30.01	28.45	27.08	25.17	30.64	36.6	38.71
150	25.74	25.54	25.13	26.38	25.64	25.39	28	27.27	26.41	30.17	28.45	27	25.23	30.64	36.6	38.91
155	25.9	25.61	25.27	26.64	25.61	25.36	28.15	27.33	26.49	30.01	28.66	27.17	25.1	30.71	36.78	38.71
160	25.81	25.46	25.17	26.49	25.71	25.46	28.15	27.27	26.54	30.15	28.61	27.08	25.33	30.81	36.88	38.91
165	25.84	25.44	25.25	26.41	25.59	25.44	28.1	27.44	26.44	30.2	28.54	27.23	25.51	30.84	36.7	38.91

Table A3.2: Experimental Data for Large Sphere, $d_p = 5.25$ cm.
Run # 2: Re = 1268.1 $Q_w = 243.4$ W/m^2 $T_{amb} = 25.2$ °C.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	24.9	24.85	24.85	24.85	24.76	24.95	25	25	25.13	25.27	25.27	24.98	25.02	25.36	25.33	25.36
5	25.08	24.92	24.87	25.13	25.02	24.98	25.23	25.27	25.25	25.64	25.39	25.3	25.3	25.64	26.92	26.84
10	25.25	25.15	25	25.39	24.95	25	25.79	25.54	25.39	26.23	25.79	25.3	25.3	25.98	28.38	28.48
15	25.36	25.17	24.92	25.61	25.13	25.08	26.15	25.71	25.56	26.91	26.1	25.61	25.13	26.54	29.71	29.99
20	25.25	25.39	25.1	25.59	25.3	25.25	26.59	26.05	25.88	27.23	26.49	25.69	25.44	27.02	30.76	31.4
25	25.41	25.36	25.08	25.92	25.33	25.17	26.76	26.23	25.84	27.71	26.84	25.79	25.1	27.56	31.74	32.53
30	25.51	25.46	24.98	25.98	25.36	25.23	27.05	26.41	25.98	28.05	27.17	26.17	25.1	27.95	32.45	33.65
35	25.66	25.36	25.17	26.05	25.41	25.27	27.25	26.66	26.12	28.45	27.3	26.38	25.17	28.4	33.35	34.35
40	25.81	25.51	25.15	26.35	25.46	25.35	27.54	26.79	26.27	28.64	27.64	26.17	25.25	28.69	34.04	35.21
45	25.84	25.59	25.2	26.41	25.49	25.54	27.66	26.98	26.2	28.94	27.79	26.66	25.23	28.99	34.33	36.04
50	25.88	25.49	25.3	26.51	25.59	25.39	27.91	27.08	26.38	29.38	27.95	26.51	25.25	29.38	34.89	36.75
55	25.76	25.56	25.23	26.54	25.76	25.51	27.98	27.1	26.38	29.48	28	26.61	25.15	29.66	35.45	37.21
60	25.9	25.66	25.23	26.59	25.66	25.66	28.13	27.15	26.54	29.66	28.42	26.84	25.27	29.86	35.81	37.8
65	26.05	25.56	25.27	26.64	25.61	25.46	28.13	27.35	26.54	29.79	28.33	26.89	25.46	30.13	36.14	38.08
70	25.98	25.64	25.39	26.74	25.79	25.49	28.38	27.46	26.76	29.94	28.45	26.95	25.39	30.25	36.44	38.46
75	25.9	25.56	25.36	26.69	25.66	25.56	28.38	27.42	26.66	30.1	28.64	26.95	25.44	30.55	36.7	38.76
80	26	25.71	25.46	26.74	25.81	25.66	28.42	27.46	26.76	29.99	28.79	27	25.3	30.74	36.78	39.15
85	26.15	25.66	25.41	26.74	25.9	25.66	28.56	27.61	26.81	30.45	28.84	27.2	25.44	30.91	37.16	39.5
90	26.23	25.69	25.2	26.81	25.84	25.69	28.69	27.61	26.81	30.5	28.89	27.49	25.35	31.15	37.31	39.91
95	26.1	25.76	25.41	26.89	25.81	25.56	28.61	27.64	26.89	30.45	28.91	27.33	25.17	31.27	37.34	39.99
100	26.08	25.88	25.39	26.81	25.92	25.69	28.74	27.69	26.84	30.56	28.96	27.56	25.17	31.23	37.61	40.16
105	26.17	25.64	25.49	26.91	25.84	25.69	28.71	27.76	26.91	30.59	29.02	27.35	25.35	31.3	37.8	40.4
110	26.12	25.69	25.44	27.08	25.92	25.54	28.81	27.81	27	30.74	29.17	27.54	25.44	31.5	37.78	40.6
115	26.1	25.9	25.23	26.84	25.9	25.61	28.76	27.84	26.81	30.64	29.17	27.49	25.1	31.45	37.83	40.62
120	26	25.71	25.36	26.98	25.71	25.76	28.71	27.74	27.08	30.86	29.3	27.56	25.41	31.71	38.28	40.75

Table A3.2: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	26.05	25.76	25.56	27.02	25.95	25.66	28.84	27.79	26.98	31.01	29.35	27.61	25.56	31.71	38.08	40.8
130	26.15	25.86	25.41	26.98	26	25.81	28.81	27.91	27.08	31.01	29.3	27.71	25.33	31.79	38.17	40.96
135	26.23	25.92	25.39	27	25.92	25.69	28.79	27.94	26.98	30.91	29.35	27.61	25.56	31.84	38.13	41.11
140	26.27	25.74	25.49	26.91	25.88	25.74	28.99	27.91	27.08	30.86	29.3	27.66	25.3	31.94	38.34	41.14
145	26.17	25.84	25.49	26.95	25.88	25.74	28.89	27.95	27.15	30.99	29.38	27.59	25.54	31.96	38.3	41.26
150	26.3	25.9	25.46	26.98	25.95	25.76	29.1	28	27	31.04	29.48	27.69	25.39	32.11	38.41	41.31
155	26.2	25.66	25.56	27.02	26.05	25.86	29.02	27.94	27.13	31.06	29.45	27.91	25.46	32.13	38.44	41.5
160	26.17	25.84	25.54	27.1	25.92	25.79	29.25	28.1	27.05	31.23	29.51	27.79	25.54	32.25	38.61	41.72
165	26.35	25.81	25.41	27.08	26.05	25.76	29.13	28.13	27.15	31.23	29.56	27.64	25.54	32.25	38.71	41.78
170	26.23	25.92	25.49	27.1	26.02	25.84	29.13	28.1	27.25	31.48	29.71	27.89	25.64	32.45	38.66	42.04
175	26.27	25.79	25.41	27.08	26.12	25.79	29.15	28	27.33	31.42	29.76	27.89	25.54	32.4	38.89	41.87
180	26.25	25.86	25.51	27.17	25.95	25.76	29.27	28.23	27.2	31.55	29.69	27.86	25.61	32.53	39	42.06
185	26.33	25.88	25.51	27.2	25.92	26.02	29.08	28.1	27.2	31.42	29.71	27.84	25.3	32.3	38.76	41.92
190	26.3	25.92	25.54	27.25	25.98	25.92	29.27	28.23	27.25	31.23	29.76	27.89	25.79	32.45	38.89	42.04

Table A3.3: Experimental Data for Large Sphere, $d_p = 5.25$ cm.
Run # 3: Re = 943.4 $Q_w = 243.4$ W/m^2 $T_{amb} = 25.0$ °C.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	24.41	24.46	24.36	24.31	24.51	24.66	24.46	24.56	24.92	25.02	25.02	25.08	24.2	25.02	24.98	25.27
5	24.51	24.46	24.46	24.66	24.31	24.56	24.81	24.71	24.87	25.2	25.25	24.98	24.74	25.35	26.54	26.64
10	24.85	24.81	24.61	25.08	24.61	24.61	25.36	25.23	25.17	25.86	25.46	25.17	24.83	25.86	28.17	28.42
15	24.92	24.79	24.54	25.23	24.69	24.79	25.86	25.46	25.35	26.64	25.9	25.2	25	26.3	29.74	30.08
20	25.13	24.98	24.69	25.56	24.87	24.74	26.35	25.76	25.61	27.2	26.44	25.46	24.83	27.05	30.96	31.74
25	25.17	24.98	24.56	25.71	25.02	24.76	26.84	26.05	25.79	27.74	26.69	25.69	24.66	27.35	32.17	33.22
30	25.41	25.13	24.74	25.86	25.23	24.92	27.2	26.33	25.9	28.35	27.15	25.9	24.74	28	33.35	34.63
35	25.69	25.15	24.66	26.02	25.1	25	27.46	26.66	26.02	28.56	27.4	26.17	24.69	28.66	34.28	35.84
40	25.64	25.3	24.95	26.33	25.25	25	27.86	26.91	26.3	29.25	27.79	26.3	24.87	29.15	35.25	36.92
45	25.69	25.3	24.9	26.27	25.39	25.1	28.1	27.13	26.38	29.42	28.1	26.46	24.85	29.48	36.09	37.92
50	25.66	25.36	24.83	26.49	25.33	25.13	28.33	27.13	26.44	29.91	28.3	26.49	24.83	29.96	36.47	38.81
55	25.76	25.33	24.92	26.59	25.56	25.23	28.42	27.23	26.51	30.15	28.4	26.46	24.85	30.33	37.24	39.64
60	25.79	25.54	25	26.81	25.64	25.3	28.76	27.56	26.81	30.4	28.84	26.81	24.85	30.81	37.85	40.42
65	25.86	25.33	24.98	26.79	25.56	25.27	28.84	27.59	26.84	30.74	28.99	26.92	24.87	31.01	38.1	41.01
70	25.79	25.59	25.05	27	25.74	25.44	29.17	27.84	27.02	30.94	29.23	27.13	24.92	31.5	38.69	41.67
75	25.9	25.56	25.02	27.02	25.66	25.46	29.15	27.95	27.1	31.12	29.35	27.2	25.15	31.61	39.15	42.21
80	26	25.49	25.2	27.1	25.79	25.44	29.33	28.02	27.13	31.45	29.48	27.33	25.13	31.96	39.42	42.72
85	26	25.61	24.98	27.23	25.86	25.41	29.4	28.15	27.15	31.42	29.69	27.44	24.9	32.17	39.61	43.14
90	26.12	25.76	25.17	27.23	25.88	25.56	29.54	28.3	27.27	31.74	29.76	27.56	24.81	32.58	40.06	43.78
95	25.98	25.49	25.13	27.25	25.88	25.46	29.64	28.2	27.27	31.94	29.96	27.71	24.98	32.81	40.22	44.05
100	26.02	25.59	25.2	27.44	26.02	25.64	29.71	28.27	27.3	32.01	30.04	27.74	24.92	32.99	40.45	44.46
105	26.15	25.66	25.13	27.33	26	25.71	29.86	28.3	27.35	32.15	30.23	27.84	24.95	33.22	40.67	44.78
110	26.15	25.84	25.3	27.27	25.92	25.49	29.96	28.33	27.44	32.2	30.17	27.79	24.95	33.22	40.83	45.05
115	26.05	25.71	25.08	27.33	26.05	25.61	29.84	28.49	27.42	32.25	30.33	27.76	25.05	33.65	41.04	45.26
120	26.1	25.69	25.3	27.42	26.05	25.74	29.96	28.51	27.49	32.4	30.42	27.98	25.05	33.65	41.21	45.39

Table A3.3: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	26.17	25.76	25.17	27.35	25.98	25.76	30.04	28.45	27.51	32.5	30.5	27.91	25.08	33.89	41.11	45.54
130	26.1	25.81	25.17	27.46	26.25	25.81	29.89	28.59	27.59	32.58	30.59	28.02	24.79	33.91	41.26	45.67
135	26.23	25.88	25.25	27.44	26.08	25.59	30.01	28.56	27.64	32.63	30.69	27.94	24.79	33.96	41.39	45.78
140	26.23	25.64	25.23	27.4	26.17	25.54	30.04	28.56	27.46	32.45	30.61	28.1	24.85	33.89	41.5	46
145	26.23	25.81	25.33	27.49	26.12	25.76	30.08	28.74	27.61	32.74	30.69	28.15	25.17	34.14	41.6	46.19
150	26.35	25.76	25.33	27.42	26.1	25.71	30.1	28.69	27.69	32.84	30.69	28.1	25.17	34.38	41.65	46.24
155	26.23	25.84	25.3	27.49	26.12	25.79	30.23	28.61	27.56	32.89	30.79	28.25	25.17	34.28	41.72	46.49
160	26.23	25.88	25.17	27.49	26.12	25.69	30.17	28.71	27.61	32.89	30.84	28.25	25.33	34.5	41.78	46.54
165	26.33	25.79	25.27	27.49	26.17	25.79	30.23	28.69	27.69	32.89	30.84	28.2	25.13	34.55	41.85	46.54
170	26.23	25.74	25.15	27.64	26.08	25.84	30.35	28.66	27.61	32.81	30.81	28.27	25.15	34.45	41.87	46.61
175	26.3	25.61	25.3	27.56	26.1	25.66	30.25	28.86	27.71	32.89	30.76	28.15	25.27	34.81	41.92	46.78
180	26.15	25.76	25.05	27.56	25.95	25.66	30.15	28.74	27.76	32.86	30.76	28.23	24.95	34.63	41.83	46.8
185	26.41	26.02	25.1	27.64	26.12	25.79	30.15	28.76	27.89	33.06	30.91	28.17	25.2	34.76	41.78	46.85
190	26.23	25.79	25.39	27.46	26.08	25.69	30.25	28.81	27.76	32.86	30.86	28.05	25.1	34.81	41.97	46.95
195	26.33	25.69	25.23	27.49	26.23	25.74	30.27	28.84	27.79	33.14	30.84	28.45	25.08	34.7	41.95	46.85
200	26.23	25.9	25.33	27.64	26.1	25.86	30.27	28.94	27.86	33.04	31.06	28.45	24.98	34.86	42.01	47.1
205	26.25	25.76	25.17	27.64	26.2	25.71	30.33	28.74	27.66	32.96	31.06	28.27	24.9	34.72	41.97	46.95
210	26.23	26.02	25.41	27.69	26.12	25.79	30.42	28.99	27.76	32.99	31.15	28.4	24.92	35.06	42	47.2
215	26.25	25.86	25.27	27.59	26.2	25.66	30.27	28.69	27.71	32.99	31.15	28.45	25.1	34.96	41.9	47.03

Table A3.4: Experimental Data for Large Sphere, $d_p = 5.25$ cm.
Run # 4: Re = 634.1 $Q_w = 243.4$ W/m^2 $T_{amb} = 25.0$ °C.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	$T_w 1$	$T_w 2$
0	24.27	24.17	24.13	23.92	24.13	24.17	24.27	24.27	24.59	24.59	24.64	24.49	23.61	24.74	24.83	24.98
5	24.34	24.15	24.2	24.39	24.1	24.34	24.69	24.49	24.64	24.98	24.87	24.49	24.49	24.92	26.41	26.56
10	24.61	24.41	24.13	24.66	24.23	24.27	25.1	24.61	24.79	25.56	25.17	24.83	24.64	25.46	28.13	28.48
15	24.85	24.71	24.23	25.2	24.31	24.36	25.86	25	24.95	26.44	25.64	25.05	24.51	25.98	29.89	30.5
20	25.02	24.69	24.34	25.44	24.64	24.44	26.41	25.44	25.27	26.95	25.86	25.17	24.54	26.66	31.64	32.42
25	25.17	24.83	24.44	25.71	24.83	24.69	26.86	25.86	25.51	27.95	26.25	25.08	24.61	27.2	32.99	34.25
30	25.35	24.9	24.36	25.98	24.9	24.66	27.46	26.02	25.69	28.42	26.46	25.64	24.69	27.89	34.5	35.81
35	25.49	25.1	24.71	26.12	25.15	24.81	28	26.51	25.86	29.23	27.1	25.81	24.59	28.61	35.75	37.46
40	25.46	25.13	24.69	26.44	25.08	24.79	28.17	26.74	26.08	29.96	27.23	25.84	24.76	29.17	36.78	38.74
45	25.59	25.39	24.76	26.66	25.35	25.1	28.76	26.95	26.23	30.66	27.51	25.98	24.76	29.94	37.9	40.28
50	25.51	25.33	24.71	26.81	25.51	24.9	28.89	27.15	26.38	30.91	27.76	26.08	24.51	30.4	38.76	41.47
55	25.9	25.56	24.87	27.02	25.66	25.17	29.33	27.56	26.71	31.58	28.1	26.38	24.76	31.01	39.84	42.62
60	25.81	25.41	24.87	27.02	25.71	25.13	29.51	27.74	26.84	31.89	28.27	26.69	24.87	31.48	40.47	43.58
65	26.02	25.49	24.9	27.3	25.74	25.3	29.74	27.95	26.95	32.28	28.49	26.86	24.9	31.86	41.26	44.67
70	26.08	25.54	24.74	27.44	25.79	25.25	30.1	28	26.98	32.74	28.81	26.89	24.54	32.5	41.7	45.49
75	26	25.81	24.87	27.61	25.86	25.33	30.25	28.1	27.37	33.11	28.96	27	24.61	32.74	42.16	46.44
80	26.23	25.79	24.85	27.59	25.88	25.3	30.5	28.23	27.27	33.06	29.27	27.23	24.64	33.2	42.67	47.08
85	26.25	25.61	25	27.71	26.1	25.51	30.76	28.56	27.51	33.53	29.48	27.37	24.79	33.67	43.29	47.92
90	26.08	25.84	25	27.84	26.23	25.64	30.79	28.61	27.54	33.74	29.48	27.49	24.64	34.06	43.39	48.46
95	26.35	25.71	25.08	27.71	26.3	25.66	30.96	28.49	27.56	34.09	29.81	27.51	24.87	34.4	43.92	48.78
100	26.41	25.88	25.05	28.02	26.23	25.74	31.08	28.81	27.64	34.33	29.91	27.59	24.66	34.47	44.19	49.37
105	26.25	25.81	25.02	27.95	26.25	25.66	31.08	28.89	27.74	34.5	30.04	27.94	24.71	34.89	44.44	49.94
110	26.41	26.02	25.08	27.94	26.41	25.69	31.17	28.94	27.86	34.72	30.2	28.1	24.83	35.04	44.78	50.3
115	26.3	25.95	25.25	28	26.44	25.81	31.35	28.96	28.02	35.01	30.27	28.13	24.71	35.33	44.85	50.79
120	26.44	25.81	25.1	28.15	26.39	25.66	31.25	29.1	27.94	34.96	30.27	27.94	24.92	35.65	45.14	50.47

Table A3.4: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	26.44	25.9	25.13	28.2	26.44	25.81	31.45	29.2	28.05	34.94	30.45	28.1	24.74	35.53	45.21	50.97
130	26.44	25.92	25.3	28.35	26.44	25.79	31.66	29.25	28.17	35.11	30.42	28.08	24.81	35.86	45.59	51.41
135	26.54	26.1	25.27	28.3	26.59	25.81	31.69	29.25	28.1	35.5	30.69	28.4	25.08	36.29	45.7	51.54
140	26.54	26.05	25.3	28.25	26.54	25.86	31.64	29.35	28.2	35.4	30.64	28.2	24.87	36.34	45.8	51.95
145	26.61	26.12	25.3	28.38	26.66	25.92	31.71	29.4	28.27	35.8	30.89	28.38	25.1	36.47	45.83	52.08
150	26.74	26.1	25.36	28.3	26.79	25.86	31.94	29.33	28.23	35.63	30.91	28.56	25	36.63	46.17	52.36
155	26.64	26.08	25.35	28.45	26.54	25.88	31.91	29.45	28.33	35.78	31.04	28.86	25.05	36.85	46.21	52.83
160	26.71	26.08	25.3	28.48	26.66	25.84	31.91	29.59	28.33	35.84	30.99	28.59	24.98	37.08	46.39	52.85
165	26.59	26.1	25.35	28.4	26.64	25.98	32.01	29.64	28.49	36.11	31.1	28.64	25.02	37.34	46.46	53.01
170	26.69	26.15	25.25	28.4	26.79	25.9	32.04	29.48	28.56	35.96	30.96	29.05	25	37.36	46.49	53.21
175	26.69	26.15	25.3	28.45	26.69	26	32.04	29.64	28.59	36.16	31.2	28.99	25.08	37.66	46.69	53.25
180	26.74	26.2	25.44	28.45	26.79	26.05	32.09	29.74	28.64	36.09	31.35	28.99	25.23	37.8	46.56	53.4
185	26.76	26.33	25.51	28.61	26.76	26.12	32.2	29.76	28.54	36.31	31.45	29.17	25.08	37.75	46.78	53.69
190	26.74	26.25	25.3	28.59	26.84	26.15	32.13	29.81	28.79	36.26	31.5	29.1	25.17	37.92	46.85	53.76
195	26.84	26.33	25.59	28.64	26.92	26.12	32.25	29.89	28.51	36.44	31.52	29.1	25.05	37.92	46.97	54.08
200	26.71	26.27	25.33	28.56	26.95	26.05	32.37	29.66	28.71	36.29	31.64	29.13	24.92	38.05	46.97	54.03
205	26.91	26.08	25.51	28.66	26.86	26.12	32.3	29.86	28.86	36.34	31.58	29.3	25.05	38.2	47.08	54.2
210	26.71	26.33	25.33	28.66	26.81	26.12	32.35	29.89	28.71	36.39	31.58	29.4	25.25	38.41	47.08	54.33
215	26.81	26.41	25.51	28.61	26.86	26.17	32.3	29.89	28.89	36.36	31.74	29.27	24.92	38.49	47.05	54.46
220	26.84	26.25	25.59	28.69	26.98	26.15	32.47	30.01	28.94	36.67	31.64	29.4	24.9	38.44	47.29	54.46
225	26.84	26.35	25.39	28.69	26.98	26.27	32.33	29.84	28.76	36.63	31.71	29.45	24.9	38.61	47.13	54.54
230	26.74	26.39	25.56	28.66	26.91	26.1	32.53	29.96	28.71	36.7	31.79	29.48	25.08	38.54	47.08	54.74
235	26.74	26.3	25.54	28.79	26.92	26.35	32.42	29.94	28.91	36.65	31.79	29.42	25.13	38.69	47.26	54.69

Table A3.5: Experimental Data for Large Sphere, $d_p = 5.25$ cm.
Run # 5: Re = 1538.8 $Q_w = 179.2$ W/m^2 $T_{amb} = 25.0$ °C.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	24.3	24.25	24.1	24.15	23.95	24	24.1	24.2	24.3	24.39	24.34	24.1	24.2	24.39	24.69	24.64
5	24.25	24.25	23.92	24.2	24	24.05	24.34	24.44	24.36	24.71	24.41	24.17	24.27	24.81	25.71	25.71
10	24.36	24.31	23.9	24.36	23.95	24.08	24.56	24.36	24.34	25.17	24.69	24.2	24.1	24.98	26.66	26.79
15	24.2	24.3	24.05	24.39	24.15	24.1	24.92	24.69	24.61	25.39	25	24.41	24.31	25.25	27.64	27.79
20	24.39	24.3	24.15	24.54	24.2	23.95	25.13	24.83	24.69	25.69	25.08	24.39	24.05	25.49	28.17	28.64
25	24.44	24.34	24.2	24.59	24.39	24.15	25.17	24.92	24.76	26	25.41	24.66	24.17	26.05	28.91	29.38
30	24.51	24.31	24.17	24.85	24.23	24.36	25.44	25.1	24.71	26.15	25.54	24.76	24.23	26.35	29.61	29.91
35	24.54	24.3	24.25	24.74	24.39	24.34	25.56	25.13	24.95	26.49	25.69	25.05	24.46	26.44	29.91	30.48
40	24.66	24.36	24.17	24.98	24.41	24.27	25.71	25.27	25.05	26.64	25.84	25	24.66	26.92	30.35	30.94
45	24.79	24.54	24.25	24.92	24.34	24.39	25.98	25.49	25.17	26.86	25.95	25.17	24.39	26.76	30.69	31.48
50	24.59	24.49	24.3	25.02	24.44	24.34	25.86	25.36	25.1	26.92	26.08	25	24.23	27.08	30.86	31.74
55	24.79	24.49	24.15	25.13	24.49	24.3	26.02	25.61	25.23	27.17	26.1	25.27	24.49	27.3	31.35	32.11
60	24.69	24.3	24.3	25.08	24.49	24.44	25.95	25.46	25.15	27.13	26.27	25.39	24.36	27.27	31.48	32.15
65	24.76	24.41	24.17	24.95	24.46	24.56	26.17	25.54	25.3	27.17	26.41	25.35	24.51	27.46	31.71	32.55
70	24.71	24.51	24.36	25.15	24.46	24.51	26.02	25.54	25.2	27.27	26.33	25.39	24.36	27.46	31.79	32.55
75	24.64	24.36	24.41	25.08	24.41	24.46	26.25	25.61	25.2	27.33	26.44	25.39	24.51	27.74	31.84	32.89
80	24.54	24.54	24.15	25.23	24.44	24.44	26.33	25.61	25.25	27.35	26.41	25.49	24.23	27.71	32.04	33.33
85	24.69	24.59	24.3	25.13	24.59	24.44	26.33	25.71	25.27	27.46	26.54	25.46	24.39	27.89	32.25	33.25
90	24.76	24.66	24.51	25.2	24.71	24.51	26.27	25.84	25.36	27.54	26.69	25.41	24.44	27.89	32.37	33.35
95	24.92	24.64	24.39	25.27	24.59	24.59	26.51	25.74	25.3	27.56	26.66	25.79	24.36	27.95	32.55	33.65
100	24.95	24.81	24.36	25.25	24.71	24.51	26.59	25.98	25.33	27.79	26.64	25.81	24.74	28.27	32.86	33.86
105	25	24.79	24.49	25.39	24.54	24.74	26.71	26.02	25.46	27.94	26.79	25.66	24.59	28.27	32.76	34.09
110	24.87	24.69	24.49	25.46	24.64	24.69	26.66	26.1	25.51	28.02	26.98	25.76	24.64	28.33	33.04	34.22
115	24.9	24.76	24.46	25.39	24.76	24.61	26.61	26.08	25.59	28.13	26.89	25.84	24.76	28.51	33.17	34.42
120	25	24.85	24.51	25.39	24.61	24.76	26.89	26.02	25.56	28.08	26.84	25.9	24.49	28.49	33.04	34.6

Table A3.5: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	25	24.76	24.31	25.49	24.66	24.61	26.84	26.08	25.64	28.2	26.95	25.88	24.76	28.56	33.16	34.74
130	25.05	24.9	24.51	25.49	24.9	24.66	26.79	26.17	25.64	28.17	27.08	25.92	24.56	28.71	33.22	34.6
135	25.15	24.9	24.41	25.54	24.85	24.81	26.89	26.17	25.61	28.25	27.1	26	24.69	28.74	33.35	34.86
140	25.1	24.85	24.56	25.35	24.9	24.61	26.98	26.02	25.71	28.27	27.13	25.81	24.79	28.69	33.4	34.7
145	25.25	24.85	24.51	25.54	24.85	24.66	26.86	26.23	25.71	28.13	27.17	25.9	24.74	28.84	33.42	34.91
150	25.13	24.98	24.64	25.61	24.92	24.83	27.05	26.25	25.59	28.3	27.17	25.98	24.71	28.76	33.42	34.94
155	25.05	25	24.76	25.69	24.95	24.85	26.89	26.3	25.69	28.35	27.27	26.02	24.66	28.76	33.42	34.99
160	25.15	24.9	24.81	25.74	24.95	24.76	26.98	26.46	25.74	28.45	27.25	26.02	24.95	28.96	33.62	35.14
165	25.2	25.05	24.81	25.74	25	24.76	26.98	26.38	25.81	28.33	27.23	25.95	24.59	28.99	33.42	35.11
170	25.25	25.05	24.76	25.64	24.85	24.81	27.02	26.44	25.81	28.49	27.15	26.15	24.79	29.02	33.71	35.24

Table A3.6: Experimental Data for Large Sphere, $d_p = 5.25$ cm.
Run # 6: Re = 1268.1 $Q_w = 179.2$ W/m^2 $T_{amb} = 24.0$ °C.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	23.36	23.26	23.31	23.23	23.31	23.51	23.41	23.41	23.69	23.74	23.74	23.59	23.29	23.83	23.83	23.83
5	23.54	23.44	23.29	23.54	23.39	23.39	23.64	23.59	23.76	24.1	23.95	23.8	23.66	24.05	25.05	25.05
10	23.71	23.56	23.41	23.76	23.46	23.46	24	23.76	23.76	24.41	24.1	23.8	23.71	24.41	26.15	26.1
15	23.85	23.76	23.61	24.05	23.61	23.56	24.44	24.2	24.02	24.98	24.54	23.92	23.64	24.83	27.08	27.35
20	23.88	23.69	23.64	24.17	23.69	23.59	24.76	24.41	24.3	25.3	24.74	24.05	23.95	25.17	28.15	28.42
25	24.05	23.9	23.66	24.25	23.85	23.66	25	24.64	24.27	25.66	24.85	24.17	23.88	25.56	28.94	29.35
30	24.1	23.92	23.69	24.49	23.92	23.79	25.33	24.92	24.41	26.1	25.27	24.36	24.17	25.9	29.51	30.27
35	24.25	24	23.8	24.74	24	23.85	25.59	24.98	24.69	26.33	25.41	24.64	23.98	26.33	30.23	30.84
40	24.3	24.05	23.8	24.64	24.05	23.8	25.64	24.98	24.61	26.59	25.69	24.66	23.74	26.54	30.61	31.5
45	24.46	24.17	23.88	24.85	24.17	24.08	25.9	25.23	24.79	26.92	25.98	24.83	23.95	26.92	31.15	32.25
50	24.51	24.23	23.98	24.85	24.23	23.92	26	25.3	24.85	26.98	25.98	24.9	24	27.13	31.66	32.71
55	24.54	24.3	24	25.02	24.25	24.15	26.12	25.51	25.1	27.23	26.25	24.9	24.08	27.44	31.89	33.2
60	24.49	24.25	24	25.02	24.2	24.15	26.38	25.69	25.05	27.35	26.35	25.15	24.13	27.54	32.25	33.47
65	24.64	24.34	24.1	24.98	24.3	24.2	26.41	25.51	25.15	27.37	26.38	25.35	23.92	27.74	32.5	33.81
70	24.59	24.25	24	24.92	24.25	24.25	26.33	25.64	25.2	27.51	26.54	25.35	24.08	27.98	32.55	34.35
75	24.56	24.36	23.92	25	24.31	24.23	26.39	25.76	25.15	27.89	26.64	25.44	23.88	28.02	32.86	34.63
80	24.54	24.3	23.92	25.02	24.3	24.25	26.56	25.81	25.2	27.89	26.84	25.35	24.13	28.23	33.06	34.91
85	24.59	24.34	24.1	25.23	24.34	24.2	26.56	25.86	25.2	27.94	26.84	25.25	24.17	28.27	33.33	35.04
90	24.59	24.3	24	25.13	24.3	24.2	26.61	25.9	25.25	27.94	26.74	25.44	24.13	28.49	33.45	35.19
95	24.66	24.36	23.95	25.2	24.25	24.2	26.64	25.88	25.3	28.02	26.89	25.66	24.13	28.54	33.4	35.53
100	24.64	24.34	24.1	25.17	24.49	24.3	26.66	25.88	25.27	28.1	26.86	25.66	24.05	28.56	33.71	35.65
105	24.59	24.34	24.1	25.17	24.49	24.3	26.71	26.1	25.39	28.13	26.79	25.59	24.27	28.79	33.91	35.72
110	24.56	24.36	23.83	25.15	24.46	24.23	26.89	25.98	25.36	28.25	27.1	25.61	24	28.86	33.71	35.94
115	24.76	24.31	23.98	25.15	24.51	24.36	26.84	26.12	25.41	28.38	27.05	25.69	23.85	28.86	33.89	36.11
120	24.64	24.46	23.95	25.08	24.36	24.17	26.81	26.05	25.35	28.42	26.95	25.69	24.02	28.99	33.99	36.11

Table A3.6: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	24.69	24.44	24.1	25.27	24.44	24.15	26.91	26	25.39	28.42	27.23	25.84	24.17	29.08	34.2	36.24
130	24.71	24.31	24.02	25.3	24.46	24.27	26.89	26.15	25.49	28.38	27.23	25.74	24.08	29.02	34.11	36.36
135	24.79	24.39	24	25.33	24.44	24.3	26.91	26.2	25.44	28.38	27.17	25.84	24.08	29.3	34.3	36.5
140	24.71	24.41	24.08	25.39	24.46	24.46	26.92	26.08	25.54	28.38	27.33	25.64	23.98	29.25	34.25	36.36
145	24.79	24.39	24.1	25.41	24.59	24.44	26.86	26.1	25.44	28.64	27.17	25.86	24.02	29.3	34.42	36.67
150	24.74	24.44	24	25.41	24.34	24.25	26.89	26.2	25.54	28.51	27.33	25.79	23.98	29.5	34.3	36.72
155	24.79	24.49	24	25.36	24.44	24.3	26.91	26.05	25.49	28.51	27.27	25.88	24.17	29.38	34.4	36.7
160	24.79	24.54	24.1	25.36	24.64	24.49	26.91	26.3	25.66	28.61	27.4	25.88	23.92	29.42	34.33	36.8
165	24.85	24.51	24.17	25.44	24.36	24.36	26.86	26.17	25.51	28.71	27.3	26.1	24	29.33	34.45	36.9
170	24.74	24.49	24.05	25.41	24.44	24.34	27.1	26.2	25.51	28.54	27.4	25.81	24	29.42	34.55	37.03
175	24.9	24.41	23.98	25.49	24.51	24.41	26.92	26.1	25.59	28.61	27.23	25.79	23.98	29.59	34.4	36.92
180	24.87	24.54	24.25	25.46	24.59	24.44	27.15	26.33	25.51	28.74	27.54	26.05	24	29.66	34.7	37.08
185	24.69	24.49	24.15	25.41	24.44	24.34	27.1	26.35	25.69	28.69	27.37	25.92	24.13	29.74	34.58	37.24
190	24.79	24.39	24.15	25.36	24.59	24.54	27.15	26.25	25.51	28.84	27.44	26	24.3	29.54	34.7	37.16
195	24.85	24.41	24.2	25.35	24.56	24.51	27.08	26.39	25.69	28.71	27.4	26.02	24.17	29.66	34.76	37.24

Table A3.7: Experimental Data for Large Sphere, $d_p = 5.25$ cm.
Run # 7: Re = 943.4 $Q_w = 179.2\ W/m^2$ $T_{amb} = 24.0\ ^oC$.
Time in (minutes), Temperature in (^oC) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	23.29	23.39	23.25	23.29	23.29	23.49	23.44	23.49	23.61	23.71	23.9	23.95	23.13	23.95	23.95	24.05
5	23.49	23.54	23.26	23.49	23.34	23.44	23.74	23.59	23.74	23.98	23.88	23.74	23.64	23.88	25.02	25.08
10	23.83	23.54	23.39	23.74	23.49	23.54	24.23	23.79	24.02	24.41	24.31	23.92	24.02	24.36	26.25	26.3
15	23.83	23.74	23.54	24.05	23.79	23.59	24.64	24.34	24	24.87	24.64	24.1	23.95	24.98	27.49	27.79
20	24	23.85	23.56	24.31	23.8	23.61	25.05	24.56	24.25	25.44	24.76	24.1	24	25.39	28.61	28.94
25	24.1	23.9	23.66	24.39	23.85	23.71	25.39	24.83	24.49	25.88	25.23	24.25	24	25.92	29.48	30.04
30	24.23	23.98	23.74	24.51	23.83	23.79	25.41	24.87	24.54	26.33	25.39	24.49	23.9	26.17	30.15	31.04
35	24.39	24.2	23.71	24.74	24.1	23.85	25.84	25.23	24.74	26.66	25.79	24.69	23.95	26.79	30.91	32.01
40	24.44	24.15	23.71	24.79	24.25	23.9	26.08	25.41	24.92	26.91	26.08	24.83	24.1	27	31.58	32.66
45	24.56	24.27	24.13	25.1	24.31	24.13	26.44	25.49	25	27.4	26.35	24.71	23.92	27.4	32.06	33.53
50	24.71	24.27	23.88	25.15	24.23	24.08	26.49	25.54	25.15	27.49	26.54	24.76	24.13	27.69	32.66	34.2
55	24.79	24.34	24	25.33	24.34	24.3	26.69	26	25.2	27.79	26.59	25.1	24.23	27.98	33.04	34.89
60	24.64	24.44	23.9	25.17	24.49	24.15	26.86	25.9	25.23	27.98	26.86	25.49	24	28.33	33.53	35.45
65	24.79	24.64	24.05	25.36	24.69	24.25	27.02	26.15	25.3	28.23	26.98	25.44	24.23	28.59	33.91	35.78
70	24.71	24.46	24.08	25.54	24.61	24.27	27.05	26.17	25.46	28.3	27.2	25.41	24.23	28.81	34.19	36.26
75	24.87	24.54	24.2	25.46	24.69	24.44	27.2	26.3	25.59	28.59	27.33	25.54	24.31	29.08	34.47	36.85
80	24.76	24.64	24.2	25.49	24.74	24.44	27.27	26.39	25.71	28.66	27.4	25.61	24.34	29.2	34.76	37.08
85	24.87	24.69	24.05	25.61	24.79	24.39	27.44	26.44	25.61	28.86	27.44	25.56	24.25	29.3	34.86	37.39
90	24.83	24.74	24.08	25.71	24.64	24.41	27.35	26.38	25.81	28.91	27.54	25.76	24.2	29.66	34.96	37.78
95	25.02	24.64	24.2	25.76	24.79	24.39	27.59	26.59	25.74	29.13	27.76	25.98	24.41	29.84	35.35	38.17
100	24.92	24.64	24.3	25.76	24.79	24.54	27.56	26.49	25.92	29	27.76	25.88	24.3	29.99	35.5	38.22
105	25.08	24.66	24.31	25.95	24.83	24.61	27.69	26.66	25.86	29.15	27.98	25.86	24.2	29.96	35.75	38.56
110	25.13	24.56	24.17	25.95	24.83	24.51	27.69	26.81	25.9	29.45	27.89	26	24.54	30.2	35.8	38.69
115	25.1	24.66	24.27	25.79	25	24.61	27.81	26.71	25.95	29.35	27.98	26.35	24.25	30.27	35.75	39.05
120	25.13	24.74	24.25	25.95	24.83	24.39	27.84	26.79	25.98	29.42	28	26.17	24.27	30.5	36.09	39.13

Table A3.7: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	25.1	24.81	24.31	25.88	25	24.61	27.89	26.91	25.88	29.61	28.2	26.27	24.36	30.59	36.06	39.3
130	25.05	24.66	24.36	26.1	25	24.51	27.84	26.81	25.95	29.5	28.2	26.35	24.39	30.66	36.34	39.4
135	25.17	24.79	24.3	26.1	24.87	24.74	27.98	26.92	26.02	29.64	28.33	26.41	24.46	30.69	36.36	39.53
140	25.17	24.81	24.31	26.05	25.05	24.56	27.98	27	26.1	29.69	28.23	26.59	24.34	30.91	36.47	39.64
145	25.3	24.76	24.46	26.12	25	24.71	28.2	26.91	26.15	29.69	28.4	26.3	24.44	30.91	36.47	39.81
150	25.33	24.87	24.39	26.05	25.17	24.79	28.17	27.13	26.23	29.89	28.42	26.46	24.56	31.06	36.72	40.11
155	25.25	24.85	24.36	25.98	25.15	24.76	28.08	27.05	26.2	29.96	28.54	26.49	24.49	31.27	36.6	40.09
160	25.2	24.81	24.23	25.92	24.9	24.85	28.17	27	26.25	29.94	28.59	26.44	24.54	31.23	36.75	40.35
165	25.2	24.76	24.31	26.08	25.05	24.66	28.2	27.1	26.3	29.99	28.27	26.54	24.54	31.23	36.9	40.35
170	25.33	24.92	24.34	26.25	25.17	24.83	28.2	27.17	26.3	30.04	28.64	26.64	24.59	31.33	37	40.35
175	25.3	24.9	24.51	26.1	25.2	24.81	28.42	27.2	26.2	30.13	28.84	26.54	24.54	31.38	36.95	40.45
180	25.35	24.9	24.51	26.17	25.15	24.81	28.3	27.3	26.25	30.25	28.48	26.84	24.54	31.42	37.16	40.62
185	25.2	24.83	24.34	26.08	25.05	24.83	28.25	27	26.25	30.25	28.84	26.59	24.3	31.55	37.03	40.8
190	25.23	24.83	24.44	26.1	25.17	24.83	28.2	27.23	26.46	30.17	28.76	26.61	24.51	31.64	37.14	40.7
195	25.35	24.76	24.46	26.23	25.05	24.81	28.3	27.2	26.35	30.3	28.56	26.84	24.64	31.66	37.26	40.89
200	25.33	24.92	24.54	26.15	25.23	24.87	28.42	27.23	26.35	30.25	28.74	26.74	24.54	31.69	37.34	40.84
205	25.33	24.98	24.44	26.2	25.08	24.92	28.42	27.23	26.3	30.2	28.79	26.86	24.34	31.69	37.16	40.84

Table A3.8: Experimental Data for Large Sphere, $d_p = 5.25$ cm.
Run # 8: Re = 634.1 $Q_w = 179.2\ W/m^2$ $T_{amb} = 24.2\ °C$.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	23.54	23.49	23.39	23.39	23.44	23.69	23.49	23.59	23.92	23.79	23.88	23.92	23.44	24.13	23.88	24.02
5	23.64	23.49	23.39	23.54	23.39	23.39	23.69	23.64	23.79	23.98	24.08	23.98	23.83	24.27	25.02	25.23
10	23.85	23.8	23.66	23.95	23.66	23.66	24.36	23.95	24.1	24.44	24.44	23.9	24	24.56	26.59	26.64
15	24	23.83	23.64	24.15	23.64	23.79	24.83	24.39	24.31	25.2	24.81	24.17	24.02	24.95	27.91	28.23
20	24.25	24	23.66	24.64	24	23.8	25.23	24.64	24.44	25.79	25.13	24.39	24.25	25.54	29.08	29.64
25	24.31	24.13	23.83	24.61	24.02	23.88	25.61	24.76	24.69	26.27	25.33	24.49	24	25.84	30.2	30.96
30	24.44	24.34	23.8	24.92	24.3	24	26.08	25.23	24.9	26.74	25.84	24.66	23.95	26.64	31.2	32.17
35	24.69	24.39	23.9	25.13	24.2	24.1	26.41	25.33	24.87	27.02	25.88	24.74	24	26.98	32.11	33.28
40	24.71	24.41	24.08	25.3	24.41	24.17	26.74	25.61	25.05	27.66	26.25	24.9	23.98	27.44	32.91	34.45
45	24.71	24.61	24.08	25.44	24.46	24.23	26.92	25.79	25.3	28.02	26.27	24.87	24.05	27.84	33.69	35.45
50	24.81	24.51	24.02	25.54	24.56	24.27	27.27	25.92	25.39	28.35	26.49	25.25	24.27	28.3	34.5	36.16
55	24.79	24.83	24.05	25.71	24.74	24.2	27.4	25.9	25.46	28.89	26.92	25.23	24.15	28.74	34.79	37
60	24.95	24.71	24.02	25.79	24.81	24.36	27.56	26.12	25.56	29.17	26.86	25.46	24.08	28.91	35.24	37.72
65	25.15	24.56	24.05	25.9	24.81	24.56	27.84	26.54	25.9	29.35	27.17	25.76	24.39	29.5	35.89	38.34
70	25.1	24.81	24.23	25.98	24.95	24.36	27.95	26.61	25.92	29.81	27.23	25.74	24.3	29.69	36.26	39
75	25.13	24.79	24.2	26.15	24.92	24.54	28.3	26.54	25.9	29.94	27.46	26	24.39	30.15	36.8	39.76
80	25.08	24.83	24.2	26.3	24.98	24.49	28.27	26.84	26.05	30.2	27.49	26.05	24.25	30.35	37.08	40.16
85	25.3	24.71	24.31	26.12	25.3	24.71	28.38	26.86	26.23	30.48	27.89	25.88	24.27	30.66	37.46	40.84
90	25.35	24.95	24.27	26.38	25.1	24.71	28.48	26.92	26.12	30.52	27.89	26.33	24.2	30.81	37.69	41.16
95	25.39	24.95	24.34	26.38	25.2	24.71	28.61	26.98	26.12	30.81	27.98	26.33	24.13	31.17	37.95	41.72
100	25.35	24.85	24.31	26.33	25.25	24.71	28.79	27.15	26.39	30.86	28.05	26.35	24.34	31.42	38.08	41.8
105	25.3	24.83	24.3	26.39	25.2	24.74	28.76	27.27	26.44	31.25	28.02	26.54	24.23	31.55	38.56	42.39
110	25.25	25.05	24.46	26.51	25.39	24.95	28.91	27.33	26.56	31.23	28.23	26.46	24.2	32.06	38.64	42.54
115	25.41	25.17	24.44	26.54	25.36	24.87	28.96	27.33	26.59	31.52	28.3	26.54	24.39	31.94	38.95	42.9
120	25.27	25.02	24.46	26.54	25.51	24.81	28.89	27.49	26.66	31.27	28.56	26.76	24.36	32.2	38.91	43.09

Table A3.8: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	$T_w 1$	$T_w 2$
125	25.51	25.15	24.56	26.81	25.33	24.85	28.99	27.4	26.61	31.84	28.4	26.71	24.34	32.58	39.1	43.36
130	25.41	25.17	24.46	26.69	25.23	24.87	29.23	27.49	26.59	31.76	28.59	26.74	24.34	32.6	39.42	43.67
135	25.51	25.08	24.44	26.59	25.46	24.79	29.27	27.54	26.91	31.66	28.64	27	24.3	32.91	39.55	44.03
140	25.49	25.1	24.39	26.76	25.39	25	29.25	27.61	26.76	32.01	28.76	27.02	24.36	32.84	39.5	44.16
145	25.54	25.1	24.49	26.76	25.54	24.95	29.3	27.71	26.84	32.15	28.79	27.08	24.56	32.99	39.84	44.34
150	25.69	25.1	24.59	26.91	25.49	25.1	29.4	27.86	26.86	32.22	28.86	27.1	24.54	33.14	39.86	44.54
155	25.56	25.08	24.49	26.74	25.51	25.13	29.45	27.71	26.92	32.35	28.94	27.17	24.51	33.35	39.94	44.83
160	25.56	25.27	24.61	26.79	25.41	25	29.56	27.79	26.92	32.15	28.94	27.08	24.51	33.3	40.06	44.85
165	25.54	25.15	24.64	26.91	25.59	25	29.5	27.91	27.05	32.28	29.05	27.15	24.64	33.6	40.04	44.97
170	25.71	25.13	24.59	26.98	25.56	25.08	29.61	27.89	27.02	32.35	28.99	27.23	24.51	33.5	40.25	45.12
175	25.69	25.27	24.69	27.02	25.64	25.08	29.66	27.86	27	32.4	29.27	27.33	24.66	33.81	40.21	45.05
180	25.76	25.23	24.66	26.92	25.66	25.23	29.61	27.98	26.98	32.58	29.23	27.42	24.46	33.71	40.42	45.39
185	25.84	25.3	24.66	26.91	25.74	25.3	29.64	27.89	26.92	32.64	29.25	27.35	24.64	33.94	40.5	45.41
190	25.69	25.35	24.69	26.95	25.79	25.1	29.79	27.95	27.02	32.66	29.33	27.37	24.56	34.14	40.37	45.44
195	25.74	25.39	24.64	26.95	25.69	25.25	29.79	28.05	27.1	32.69	29.56	27.61	24.66	34.01	40.62	45.7
200	25.64	25.39	24.71	27	25.64	25.1	29.74	27.98	27.13	32.79	29.4	27.64	24.69	34.2	40.5	45.8
205	25.88	25.59	24.66	27.05	25.79	25.1	30.04	28.08	27.23	32.86	29.48	27.51	24.66	34.22	40.65	45.9
210	25.98	25.44	24.64	27	25.84	25.25	29.94	28	27.23	32.84	29.4	27.49	24.59	34.35	40.6	45.9
215	25.84	25.49	24.69	27.15	25.74	25.3	29.89	28.05	27.37	32.89	29.35	27.37	24.69	34.45	40.65	45.8
220	25.9	25.51	24.81	27.27	25.95	25.23	29.81	28.17	27.2	32.96	29.56	27.81	24.66	34.33	40.84	45.92
225	25.84	25.46	24.87	27.1	25.69	25.41	29.96	28.2	27.25	32.84	29.64	27.69	24.49	34.47	40.65	45.97
230	25.81	25.44	24.76	27.23	25.81	25.25	30.04	28.23	27.2	33.01	29.51	27.66	24.76	34.38	40.72	46.29
235	25.98	25.46	24.98	27.17	25.88	25.36	30.01	28.2	27.35	33.01	29.66	27.71	24.61	34.7	40.89	46.17
240	25.95	25.36	24.92	27.17	25.81	25.41	30.01	28.2	27.44	33.06	29.48	27.61	24.71	34.6	41.01	46.29
245	25.84	25.3	24.9	27.25	25.92	25.2	29.84	28.08	27.42	33.14	29.79	27.94	24.61	34.63	40.99	46.44
250	25.92	25.35	24.76	27.2	25.84	25.35	29.99	28.23	27.33	32.99	29.64	27.64	24.51	34.72	40.89	46.39
255	25.95	25.46	24.87	27.23	26	25.36	30.05	28.2	27.37	33.04	29.74	27.98	24.71	34.76	41.04	46.39
260	25.9	25.46	24.81	27.33	25.95	25.36	30.01	28.33	27.44	33.11	29.59	27.89	24.74	34.84	41.01	46.46

Table A3.9: Experimental Data for Large Sphere, $d_p = 5.25$ cm.
Run # 9: Re = 1538.8 $Q_w = 79.4\ W/m^2$ $T_{amb} = 23.5\ ^oC$.
Time in (minutes), Temperature in (^oC) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	$T_w 1$	$T_w 2$
0	22.92	22.88	22.83	22.92	22.73	22.77	22.88	22.98	22.8	23.15	23.1	23.05	23.25	23.2	23.34	23.34
5	23.41	23.13	23.02	23.17	23.02	22.88	23.23	23.17	23.13	23.36	23.26	23.13	23.56	23.31	23.85	23.85
10	23.59	23.54	23.25	23.54	23.25	23.1	23.64	23.34	23.26	23.85	23.61	23.23	23.9	23.61	24.51	24.34
15	23.8	23.51	23.41	23.61	23.31	23.26	23.85	23.71	23.54	24.08	23.64	23.25	24.02	23.83	25.17	24.87
20	23.85	23.8	23.56	23.76	23.46	23.36	24.2	23.8	23.79	24.41	23.98	23.41	24.17	24.08	25.61	25.46
25	24.2	23.85	23.61	23.95	23.76	23.56	24.3	23.95	23.88	24.46	24.08	23.69	24.31	24.36	25.86	25.81
30	24.1	23.88	23.74	23.92	23.64	23.54	24.34	24.15	23.92	24.64	24.13	23.69	24.08	24.59	26.17	26.17
35	24.17	23.92	23.79	24.13	23.69	23.56	24.51	24.27	23.98	24.9	24.27	23.83	24.17	24.66	26.41	26.66
40	24.15	23.95	23.8	24.05	23.76	23.66	24.66	24.2	24.05	24.92	24.44	23.85	24.3	24.79	26.89	26.84
45	24.13	24.02	23.83	24.13	23.88	23.79	24.51	24.51	24.13	25.08	24.59	24.02	24.2	24.87	26.89	26.92
50	24.1	24	23.9	24.1	23.8	23.8	24.54	24.49	24.23	25	24.66	24.27	24.23	25	26.95	27.3
55	24.25	24.15	23.83	24.25	24.05	23.98	24.79	24.59	24.27	25.3	24.71	24.31	24.36	25.1	27.3	27.4
60	24.34	24.1	23.85	24.2	23.9	23.76	24.85	24.66	24.36	25.3	24.81	24.1	24.31	25.3	27.35	27.69
65	24.39	24.25	23.85	24.49	24.15	24	24.95	24.59	24.31	25.35	24.81	24.41	24.36	25.54	27.4	27.81
70	24.31	24.23	24.02	24.31	24.08	23.88	24.9	24.66	24.54	25.51	24.92	24.34	24.2	25.36	27.56	27.81
75	24.39	24.2	24.15	24.44	24.1	24	24.92	24.69	24.56	25.44	24.95	24.46	24.23	25.49	27.66	27.95
80	24.46	24.2	24.15	24.39	24.1	23.95	24.95	24.81	24.51	25.64	25.05	24.36	24.46	25.54	27.64	28.1
85	24.61	24.27	24.13	24.56	24.23	24.17	25.2	24.95	24.54	25.66	25.13	24.54	24.44	25.79	27.89	28.08
90	24.54	24.39	24.05	24.54	24.1	24.1	25.13	24.87	24.51	25.56	25.1	24.66	24.51	25.66	27.95	28.2
95	24.56	24.23	24.17	24.46	24.27	24.17	25.2	24.9	24.64	25.86	25.33	24.64	24.59	25.76	28	28.38
100	24.44	24.3	24.25	24.54	24.15	24.3	25.2	24.9	24.66	25.76	25.15	24.61	24.36	25.66	28	28.4
105	24.61	24.41	24.27	24.56	24.23	24.23	25.15	24.95	24.61	25.66	25.2	24.61	24.56	25.81	28.1	28.54
110	24.49	24.39	24.25	24.64	24.2	24.25	25.25	24.87	24.71	25.74	25.3	24.76	24.61	26.02	28.13	28.74
115	24.69	24.49	24.25	24.54	24.25	24.25	25.08	25.02	24.66	25.81	25.35	24.9	24.56	26.05	28.25	28.66
120	24.64	24.39	24.3	24.69	24.39	24.2	25.17	24.98	24.66	26.05	25.36	24.98	24.71	26	28.3	28.91

Table A3.9: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	24.56	24.49	24.25	24.71	24.3	24.3	25.3	25.05	24.71	25.92	25.44	24.85	24.46	26.02	28.23	28.89
130	24.74	24.44	24.3	24.64	24.3	24.25	25.27	25.02	24.87	25.86	25.41	24.92	24.59	26.17	28.38	28.76
135	24.66	24.51	24.46	24.76	24.31	24.27	25.39	25.2	24.69	26.08	25.54	24.87	24.59	26.12	28.33	28.84
140	24.64	24.64	24.25	24.64	24.49	24.39	25.49	25.15	24.83	26.15	25.41	24.83	24.69	26.25	28.51	28.96
145	24.76	24.51	24.41	24.81	24.41	24.41	25.44	25.15	24.98	26.1	25.56	25.02	24.59	26.27	28.51	29.02
150	24.64	24.54	24.34	24.79	24.59	24.49	25.44	25.23	24.98	26.12	25.54	24.87	24.69	26.38	28.38	28.99
155	24.92	24.49	24.34	24.74	24.44	24.44	25.46	25.23	25.05	26.2	25.46	24.85	24.66	26.3	28.49	29
160	24.81	24.66	24.36	24.85	24.51	24.46	25.39	25.39	24.92	26.23	25.64	25.15	24.92	26.27	28.69	29.13
165	24.85	24.54	24.44	24.95	24.54	24.64	25.59	25.44	25.02	26.15	25.71	24.98	24.83	26.39	28.56	29.38
170	24.85	24.56	24.41	24.85	24.51	24.41	25.56	25.41	25.08	26.12	25.71	24.98	24.79	26.41	28.56	29.08

Table A3.10: Experimental Data for Large Sphere, $d_p = 5.25$ cm.
Run # 10: Re = 1268.1 $Q_w = 79.4$ W/m^2 $T_{amb} = 23.5$ °C.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	23.36	23.41	23.31	23.31	23.25	23.25	23.31	23.31	23.51	23.56	23.41	23.36	23.66	23.56	23.66	23.61
5	23.64	23.49	23.44	23.54	23.34	23.34	23.39	23.54	23.51	23.8	23.56	23.26	23.95	23.71	24.2	24.1
10	23.85	23.8	23.39	23.69	23.54	23.39	23.85	23.76	23.71	24.1	23.8	23.56	24.1	23.9	24.9	24.81
15	24.1	23.9	23.71	23.95	23.71	23.71	24.05	24.05	23.9	24.25	24.15	23.61	24.25	24.15	25.35	25.49
20	24	24.05	23.76	24.1	23.76	23.66	24.39	24.15	24.02	24.74	24.27	23.79	24.31	24.46	25.92	25.88
25	24.17	24.08	23.92	24.31	23.92	23.88	24.56	24.46	24.17	24.9	24.56	23.98	24.51	24.76	26.23	26.51
30	24.27	24.13	24.02	24.31	24.02	23.79	24.66	24.36	24.3	24.87	24.69	23.95	24.49	24.92	26.64	26.69
35	24.36	24.17	24.08	24.46	24.17	23.92	24.81	24.61	24.34	25.17	24.79	24.15	24.59	25.02	26.98	27.15
40	24.51	24.17	23.98	24.36	24.08	23.98	24.92	24.61	24.36	25.23	24.71	24.36	24.56	25.13	27.23	27.59
45	24.41	24.31	24.08	24.51	24.17	23.98	25.08	24.71	24.54	25.36	25.08	24.44	24.59	25.46	27.44	27.64
50	24.64	24.25	24.2	24.59	24.25	24.1	25.08	24.83	24.49	25.74	24.92	24.39	24.59	25.46	27.79	28.1
55	24.54	24.25	24.2	24.64	24.3	24.2	25.02	24.83	24.49	25.71	25.17	24.59	24.64	25.61	27.89	28.4
60	24.61	24.36	24.17	24.71	24.31	24.17	25.2	24.95	24.69	25.69	25.23	24.54	24.44	25.79	27.94	28.4
65	24.64	24.49	24.17	24.79	24.41	24.23	25.33	24.87	24.76	25.74	25.35	24.66	24.51	25.88	27.95	28.61
70	24.56	24.41	24.2	24.71	24.31	24.31	25.3	24.9	24.76	25.86	25.41	24.61	24.56	25.86	28.23	28.74
75	24.56	24.46	24.31	24.9	24.36	24.27	25.35	25.2	24.71	25.9	25.44	24.81	24.66	26.15	28.38	28.89
80	24.66	24.46	24.27	24.66	24.46	24.36	25.25	25	24.76	25.9	25.36	24.66	24.51	26.05	28.48	28.94
85	24.46	24.41	24.27	24.92	24.51	24.31	25.36	25.08	24.9	26.1	25.46	24.66	24.61	26.1	28.66	29.25
90	24.61	24.46	24.27	24.85	24.46	24.36	25.49	25.1	24.87	26.17	25.64	24.92	24.44	26.27	28.49	29.3
95	24.79	24.49	24.44	24.87	24.49	24.44	25.56	25.23	24.9	26.08	25.69	25.15	24.61	26.44	28.71	29.38
100	24.54	24.49	24.39	24.9	24.44	24.44	25.49	25.25	24.98	26.23	25.66	24.92	24.64	26.38	28.84	29.45
105	24.56	24.61	24.46	25.05	24.46	24.27	25.51	25.25	25.1	26.27	25.79	24.95	24.64	26.44	29	29.56
110	24.85	24.56	24.41	25	24.66	24.46	25.64	25.44	24.81	26.25	25.76	25.13	24.76	26.39	28.79	29.54
115	24.66	24.61	24.36	24.9	24.61	24.61	25.59	25.25	24.87	26.3	25.76	25.08	24.74	26.66	28.99	29.64
120	24.74	24.54	24.49	24.98	24.69	24.49	25.76	25.36	25.05	26.41	25.88	25.39	24.79	26.59	29	29.66

Table A3.10: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	24.92	24.59	24.49	25.02	24.59	24.54	25.71	25.51	24.98	26.27	25.92	25.17	24.79	26.71	28.94	29.86
130	24.85	24.71	24.46	25	24.66	24.51	25.79	25.44	25.15	26.35	25.76	25.15	24.85	26.69	29.08	29.89
135	24.69	24.69	24.44	25.08	24.69	24.54	25.76	25.36	25.13	26.51	25.84	25.3	24.74	26.51	29.15	29.86
140	24.81	24.61	24.46	25.1	24.66	24.61	25.69	25.49	25.2	26.54	25.95	25.36	24.81	26.74	29.17	29.94
145	24.95	24.71	24.51	25.1	24.76	24.66	25.79	25.35	25.25	26.59	25.98	25.3	24.76	26.74	29.25	29.99
150	24.83	24.64	24.59	25.08	24.79	24.54	25.76	25.41	25.36	26.46	25.95	25.27	24.74	26.76	29.08	30.05
155	24.76	24.71	24.46	25.1	24.85	24.76	25.92	25.39	25.2	26.59	26.1	25.25	24.56	26.84	29.33	30.17
160	24.95	24.66	24.51	25.15	24.76	24.61	25.9	25.54	25.17	26.49	26	25.17	24.9	26.91	29.27	30.08
165	24.81	24.76	24.51	25.1	24.76	24.61	25.74	25.49	25.25	26.74	25.98	25.35	24.61	26.89	29.3	30.17
170	24.87	24.79	24.49	25.17	24.74	24.69	25.9	25.51	25.1	26.54	26.05	25.25	24.81	27.05	29.27	30.23
175	25	24.81	24.56	25.15	24.76	24.76	25.84	25.44	25.25	26.66	26.17	25.3	24.79	26.89	29.35	30.17

Table A3.11: Experimental Data for Large Sphere, $d_p = 5.25$ cm.
Run # 11: Re = 943.4 $Q_w = 79.4$ W/m^2 $T_{amb} = 23.5$ °C.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	$T_w 1$	$T_w 2$
0	22.85	23	23	22.95	23.15	23.05	22.9	23.1	23.31	23.26	23.36	23.41	23.17	23.41	23.46	23.36
5	23.25	23.1	23.1	23.1	23	23.1	23.25	23.15	23.44	23.49	23.49	23.39	23.49	23.44	23.88	23.95
10	23.56	23.26	23.17	23.41	23.23	23.13	23.41	23.31	23.41	23.76	23.56	23.56	23.85	23.66	24.46	24.46
15	23.66	23.46	23.26	23.61	23.41	23.17	23.98	23.56	23.61	24	23.76	23.56	24.1	23.9	25.1	25.35
20	23.88	23.69	23.39	23.69	23.49	23.39	24.02	23.88	23.69	24.44	24.08	23.79	24.17	24.23	25.59	25.79
25	23.98	23.79	23.59	24.02	23.69	23.44	24.27	24.02	23.85	24.66	24.23	23.61	24.27	24.31	26.15	26.38
30	24.2	23.95	23.69	24.3	23.64	23.49	24.49	24.15	23.92	24.85	24.46	23.74	24.13	24.56	26.66	26.76
35	24.13	23.92	23.83	24.13	23.92	23.64	24.76	24.41	24.17	25.02	24.56	23.79	24.41	24.83	27.13	27.27
40	24.15	24.15	23.76	24.46	23.8	23.61	24.85	24.51	24.25	25.3	24.64	24.25	24.25	24.95	27.3	27.66
45	24.41	24.17	23.88	24.31	24.13	23.74	25.08	24.51	24.41	25.39	24.95	24.08	24.36	25.2	27.51	28.08
50	24.44	24.2	23.95	24.59	24	23.95	25.25	24.64	24.44	25.54	24.79	24.44	24.49	25.46	27.89	28.35
55	24.49	24.34	24	24.74	24	24.05	25.23	25.02	24.46	25.66	25.15	24.46	24.46	25.71	28.08	28.69
60	24.61	24.41	24.02	24.83	24.27	24.08	25.41	24.92	24.69	25.84	25.23	24.3	24.69	25.79	28.3	29
65	24.66	24.46	24.27	24.81	24.31	24.02	25.56	25.17	24.74	25.92	25.44	24.39	24.49	26.02	28.49	29.27
70	24.74	24.54	24.15	24.92	24.39	24.05	25.61	25.13	25	26.15	25.46	24.71	24.56	26.05	28.79	29.5
75	24.71	24.61	24.27	24.95	24.46	24.27	25.74	25.15	24.95	26.35	25.56	24.71	24.66	26.2	28.76	29.74
80	24.85	24.66	24.17	25.2	24.46	24.13	25.71	25.25	24.9	26.3	25.76	24.66	24.9	26.35	29.13	30.01
85	24.85	24.76	24.27	25.1	24.56	24.36	25.88	25.3	24.85	26.25	25.9	24.95	24.61	26.54	29.02	30.01
90	24.87	24.64	24.34	25.17	24.49	24.39	25.95	25.41	25.17	26.56	25.81	24.95	24.76	26.61	29.54	30.38
95	24.95	24.66	24.46	25.15	24.66	24.41	26.02	25.44	25.05	26.59	26.02	25	24.87	26.64	29.51	30.35
100	24.87	24.69	24.59	25.23	24.69	24.49	25.86	25.46	25.05	26.59	26	24.81	24.71	26.91	29.54	30.56
105	24.95	24.76	24.46	25.25	24.81	24.51	26.05	25.56	25.27	26.76	26.05	25.17	24.83	26.86	29.64	30.79
110	25.05	24.66	24.61	25.1	24.61	24.56	26.12	25.69	25.2	26.84	26.17	24.92	24.92	27.02	29.71	30.64
115	24.95	24.9	24.61	25.3	24.71	24.51	26.12	25.69	25.15	26.74	26.1	25.1	24.9	27.25	29.84	31.01
120	24.98	24.74	24.49	25.33	24.74	24.54	26.15	25.66	25.23	26.76	26.23	25.23	24.74	27.1	29.81	31.04

Table A3.11: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	25.05	24.9	24.46	25.3	24.71	24.56	26.27	25.79	25.36	26.95	26.15	25.23	24.81	27.15	29.89	31.12
130	25	24.81	24.56	25.25	24.66	24.51	26.3	25.64	25.41	27	26.35	25.33	24.79	27.15	29.74	31.35
135	25.05	24.71	24.51	25.35	24.85	24.71	26.17	25.79	25.44	26.92	26.33	25.49	24.9	27.27	30.04	31.27
140	24.98	24.79	24.44	25.36	24.79	24.64	26.3	25.9	25.27	26.95	26.35	25.36	24.83	27.35	30.1	31.35
145	25.08	24.87	24.54	25.33	24.79	24.59	26.41	25.81	25.46	27.17	26.33	25.36	25.08	27.42	30.05	31.58
150	25.13	24.92	24.64	25.46	24.74	24.79	26.25	26	25.51	27.1	26.39	25.36	24.87	27.51	30.05	31.6
155	25.08	24.92	24.69	25.41	24.92	24.74	26.39	25.9	25.44	27.17	26.41	25.39	24.81	27.51	30.17	31.66
160	25.2	24.9	24.66	25.39	25	24.71	26.51	25.88	25.56	27.25	26.54	25.36	25.08	27.76	30.25	31.5
165	25.15	24.95	24.66	25.54	25	24.81	26.46	25.88	25.49	27.2	26.54	25.35	24.81	27.59	30.23	31.58
170	25.25	24.95	24.66	25.39	24.9	24.81	26.41	26.02	25.54	27.37	26.49	25.54	24.95	27.69	30.33	31.61
175	25.08	25.08	24.83	25.51	25.13	24.79	26.39	25.9	25.61	27.3	26.71	25.76	24.98	27.66	30.45	31.69
180	25.13	24.98	24.64	25.51	24.79	24.87	26.49	26	25.61	27.35	26.49	25.61	24.92	27.61	30.25	31.69
185	25.3	24.9	24.85	25.59	25	24.71	26.41	26.12	25.46	27.37	26.76	25.61	24.98	27.81	30.4	31.81
190	25.25	25.1	24.76	25.69	25.15	24.71	26.56	25.98	25.54	27.27	26.64	25.79	25.15	27.94	30.42	31.86
195	25.2	25.05	24.76	25.69	25.05	24.85	26.56	25.98	25.79	27.37	26.51	25.74	25.2	27.89	30.52	31.81
200	25.17	25.13	24.79	25.61	25.02	24.92	26.64	26	25.84	27.49	26.64	25.69	25.2	27.84	30.42	31.89
205	25.25	25.1	24.76	25.54	25.2	24.95	26.61	26.08	25.79	27.33	26.66	25.69	25.08	27.91	30.48	31.91
210	25.35	25.2	24.9	25.69	25.15	25	26.61	26.08	25.76	27.51	26.81	25.71	25.17	27.91	30.5	32.11
215	25.35	25.2	24.9	25.88	25.15	25.15	26.81	26.23	25.71	27.49	26.95	25.71	25.27	28	30.55	31.89

Table A3.12: Experimental Data for Large Sphere, $d_p = 5.25$ cm.
Run # 12: Re = 634.1 $Q_w = 79.4\ W/m^2$ $T_{amb} = 25.2\ °C$.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	24.36	24.61	24.56	24.36	24.46	24.71	24.51	24.56	24.81	25	25.05	24.85	24.36	25	24.9	25.05
5	24.49	24.3	24.49	24.39	24.59	24.49	24.59	24.71	24.98	24.92	24.98	24.83	24.98	25.08	25.49	25.54
10	24.56	24.51	24.61	24.66	24.41	24.46	24.95	24.66	24.95	25.1	25.05	24.76	25.1	25.15	26.2	26.2
15	24.74	24.74	24.64	24.74	24.64	24.59	25.13	24.87	25.1	25.54	25.2	25.05	25.05	25.44	26.64	26.91
20	24.9	24.74	24.54	24.9	24.54	24.49	25.25	24.95	25.1	25.71	25.39	25	25.05	25.71	27.35	27.4
25	25.05	24.9	24.61	25.05	24.71	24.61	25.59	25.35	25.2	26.02	25.54	25.15	25.1	25.74	27.64	27.94
30	25.02	24.83	24.64	25.13	24.83	24.69	25.76	25.27	25.3	26.08	25.84	25.3	25.15	25.98	28.2	28.4
35	25.02	24.92	24.54	25.08	24.87	24.74	25.76	25.46	25.39	26.12	25.59	25.25	25.25	26.12	28.35	28.69
40	25.2	25	24.81	25.25	24.95	24.81	26.02	25.59	25.44	26.38	25.92	25.35	25.15	26.38	28.69	29.15
45	25.1	25	24.81	25.49	24.95	24.81	26.12	25.54	25.46	26.56	26	25.41	24.98	26.56	29.08	29.64
50	25.36	25.23	24.83	25.41	25.08	24.87	26.25	25.81	25.49	26.74	26.44	25.44	25.05	26.74	29.38	30.04
55	25.15	25.2	24.76	25.49	24.95	25.05	26.27	25.74	25.56	26.86	26.2	25.56	25.1	26.81	29.51	30.4
60	25.39	25.15	24.81	25.49	25.05	24.95	26.51	25.88	25.61	27.13	26.41	25.51	25.27	27	29.86	30.84
65	25.35	25.2	24.95	25.64	25.15	25.05	26.33	26.02	25.79	27.27	26.61	25.64	25.35	27.27	29.96	31.08
70	25.49	25.2	24.87	25.74	25.1	25.05	26.74	26.08	25.79	27.27	26.51	25.39	25.25	27.42	30.38	31.45
75	25.51	25.27	24.98	25.76	25.27	25.13	26.74	26.15	25.71	27.37	26.71	25.76	25.33	27.56	30.4	31.5
80	25.51	25.33	24.92	25.76	25.27	25.17	26.69	26.2	25.92	27.61	26.76	25.88	25.36	27.76	30.66	31.81
85	25.66	25.46	24.9	25.81	25.35	25	26.76	26.15	25.9	27.71	26.86	26.05	25.41	27.81	30.76	32.06
90	25.54	25.35	25.05	25.88	25.25	25.2	26.95	26.27	26.05	27.84	26.79	26.15	25.36	27.95	31.15	32.25
95	25.79	25.49	25.15	25.98	25.3	25.25	26.95	26.41	26.02	27.76	26.86	25.88	25.44	28.08	31.17	32.42
100	25.69	25.49	25.2	25.98	25.39	25.3	27.1	26.41	26.23	27.98	27.13	25.79	25.49	28.38	31.33	32.53
105	25.81	25.56	25.08	26	25.41	25.27	27.13	26.44	26.27	28	27.1	26.02	25.54	28.38	31.38	32.89
110	25.86	25.51	25.27	26	25.51	25.27	27.13	26.64	26.2	28	27.1	25.95	25.41	28.59	31.48	32.91
115	25.92	25.54	25.2	26.08	25.69	25.39	27.3	26.66	26.15	28.15	27.3	26.2	25.36	28.45	31.52	33.14
120	25.81	25.61	25.27	26.25	25.61	25.36	27.17	26.59	26.38	28.02	27.42	26.33	25.69	28.56	31.6	33.25

Table A3.12: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	25.69	25.59	25.25	26.27	25.54	25.3	27.44	26.66	26.17	28.13	27.17	26.33	25.54	28.79	31.69	33.38
130	25.9	25.61	25.27	26.3	25.61	25.46	27.37	26.59	26.25	28.3	27.44	26.64	25.46	28.74	31.86	33.42
135	25.92	25.59	25.25	26.17	25.59	25.44	27.35	26.61	26.35	28.2	27.35	26.1	25.46	28.91	31.81	33.65
140	25.92	25.74	25.3	26.38	25.59	25.49	27.44	26.71	26.35	28.49	27.54	26.49	25.61	28.91	32.13	33.55
145	25.95	25.76	25.36	26.25	25.61	25.36	27.42	26.74	26.33	28.51	27.61	26.46	25.66	29.05	31.89	33.65
150	26.02	25.74	25.39	26.27	25.74	25.49	27.59	26.81	26.38	28.54	27.49	26.46	25.51	29.15	32.13	33.91
155	25.98	25.79	25.35	26.33	25.64	25.54	27.49	26.81	26.46	28.56	27.51	26.61	25.51	29.23	31.99	34.01
160	26.12	25.84	25.35	26.38	25.84	25.59	27.54	26.74	26.38	28.48	27.71	26.46	25.51	29.27	32.09	34.01
165	25.95	25.81	25.41	26.39	25.76	25.51	27.61	26.86	26.38	28.61	27.71	26.41	25.54	29.13	32.2	34.14
170	25.95	25.66	25.36	26.25	25.9	25.51	27.61	27.13	26.46	28.69	27.71	26.54	25.59	29.33	32.2	34.2
175	25.95	25.71	25.2	26.49	25.86	25.56	27.56	26.79	26.61	28.71	27.86	26.51	25.64	29.48	32.3	34.22
180	26.08	25.76	25.36	26.33	25.81	25.61	27.54	26.81	26.38	28.56	27.66	26.61	25.59	29.48	32.35	34.45
185	25.95	25.81	25.56	26.39	25.81	25.71	27.66	26.76	26.44	28.69	27.84	26.64	25.61	29.56	32.45	34.38
190	25.95	25.86	25.35	26.35	25.74	25.74	27.66	26.89	26.59	28.89	27.64	26.64	25.54	29.64	32.42	34.58
195	25.88	25.74	25.35	26.38	25.88	25.59	27.64	27	26.66	28.71	27.76	26.66	25.71	29.66	32.35	34.45
200	25.95	25.71	25.44	26.39	25.81	25.56	27.66	26.92	26.54	28.84	27.84	26.79	25.54	29.54	32.37	34.53
205	25.98	25.69	25.36	26.38	25.79	25.64	27.64	26.91	26.51	28.91	27.91	26.76	25.46	29.61	32.45	34.47
210	25.92	25.79	25.35	26.46	25.92	25.64	27.79	27	26.71	28.91	27.91	26.86	25.54	29.69	32.45	34.6
215	26	25.74	25.44	26.39	25.88	25.69	27.71	26.89	26.49	28.84	27.94	26.64	25.56	29.86	32.6	34.7
220	25.98	25.79	25.46	26.46	25.88	25.74	27.74	27.05	26.69	28.84	28.02	26.69	25.66	29.79	32.58	34.67
225	25.98	25.84	25.44	26.51	25.88	25.64	27.79	27	26.69	28.74	27.94	26.74	25.64	29.84	32.53	34.63
230	25.95	25.76	25.44	26.54	25.86	25.76	27.81	27.02	26.61	28.91	28.05	26.71	25.59	29.76	32.5	34.74
235	25.86	25.66	25.44	26.59	25.71	25.81	27.81	26.92	26.61	29	28	26.71	25.71	30.04	32.55	34.79
240	25.95	25.71	25.46	26.49	26	25.56	27.76	27	26.61	28.91	28.15	26.95	25.51	29.76	32.5	34.7
245	25.92	25.69	25.33	26.51	25.88	25.74	27.69	27.1	26.76	28.91	27.95	26.91	25.71	29.86	32.55	34.79
250	26.1	25.76	25.46	26.49	25.86	25.76	27.71	27	26.71	29	28.1	26.91	25.51	29.86	32.64	35.01
255	26.05	25.86	25.36	26.46	25.86	25.71	27.84	27.1	26.61	28.99	28.05	26.92	25.74	30.04	32.55	35.04
260	26.1	25.86	25.61	26.59	25.9	25.71	27.81	27.08	26.69	28.89	28.05	26.86	25.61	29.96	32.53	34.89

Table A3.12: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
265	26.05	25.95	25.54	26.44	25.86	25.79	27.76	27.08	26.79	29.13	28.13	26.92	25.69	29.89	32.76	34.76
270	26.08	25.92	25.54	26.56	25.92	25.79	27.84	27.05	26.84	29.02	28.08	26.98	25.49	30.04	32.58	35.04
275	26.1	25.98	25.54	26.59	26.02	25.79	27.81	26.92	26.74	28.99	28.08	27.02	25.64	29.89	32.66	34.76
280	26.23	25.92	25.69	26.66	25.92	25.84	27.89	27.2	26.81	29.15	28.15	26.91	25.95	29.96	32.64	34.89
285	26.2	25.86	25.61	26.56	26	25.66	27.84	27.15	26.86	28.96	28.25	27.15	25.74	30.13	32.69	34.91
290	26.17	25.88	25.59	26.51	26.02	25.74	27.74	27.15	26.59	29.02	28.17	27.08	25.61	30.01	32.66	35.04

Table A4.1: Experimental Data for Small Rashig Ring, $d_p = 3.27$ cm.
Run # 1: Re = 1035.5 $Q_w = 243.4\ W/m^2$ $T_{amb} = 25.5\ ^oC$.
Time in (minutes), Temperature in (^oC) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	24.87	24.83	24.87	24.59	24.79	24.92	24.92	24.92	25	25.2	25.15	25.35	25.25	25.35	25.1	25.1
5	25.08	25.08	24.92	24.98	24.98	24.87	25.11	25.17	25.23	25.23	25.36	25.23	25.33	25.46	26.2	26.46
10	25.27	25.02	25.02	25.51	25.17	25.08	25.51	25.33	25.23	25.51	25.61	25.33	25.51	25.81	27.25	27.95
15	25.33	25.33	24.87	25.76	25.33	25.23	25.79	25.66	25.33	25.81	25.81	25.33	25.56	25.86	27.95	29
20	25.51	25.23	25.08	25.95	25.66	25.41	26.09	26	25.69	26.23	26.27	25.79	25.64	26.27	28.66	30.13
25	25.51	25.51	25.13	26.2	25.71	25.56	26.41	26.39	25.71	26.61	26.56	25.86	25.46	26.76	29	30.89
30	25.66	25.51	25.33	26.3	25.86	25.71	26.72	26.59	26.02	27.13	26.98	26.33	25.88	27.13	29.54	31.69
35	25.88	25.59	25.27	26.56	26.17	25.92	26.92	26.81	26.27	27.27	27.27	26.56	25.92	27.61	29.76	32.28
40	25.81	25.71	25.36	26.61	26.27	26	27.11	26.95	26.38	27.61	27.66	26.95	25.64	28	29.99	32.91
45	25.71	25.66	25.41	26.81	26.27	26	27.38	27.15	26.41	27.95	27.84	27.2	25.71	28.2	30.38	33.47
50	25.98	25.74	25.59	26.86	26.33	26.17	27.52	27.37	26.54	28.17	28.23	27.27	26.05	28.61	30.5	33.91
55	26.05	25.86	25.56	27.08	26.44	26.15	27.75	27.42	26.59	28.42	28.13	27.54	25.81	29.02	30.59	34.33
60	25.95	25.86	25.61	27.02	26.49	26.39	27.89	27.54	26.81	28.76	28.35	27.76	26.17	29.15	30.71	34.63
65	25.98	25.79	25.54	27.15	26.61	26.33	27.97	27.56	26.89	28.79	28.54	27.94	25.86	29.45	30.91	34.81
70	26.1	25.95	25.76	27.27	26.69	26.49	28.12	27.64	26.98	28.96	28.81	27.91	25.98	29.56	31.1	35.3
75	26.17	25.95	25.66	27.35	26.66	26.51	28.25	27.84	27.17	29.15	29	28.15	25.98	29.91	31.17	35.58
80	26.15	26.05	25.64	27.27	26.74	26.44	28.35	27.81	27.17	29.42	28.96	28.27	25.95	29.99	31.08	35.72
85	26.08	25.92	25.84	27.35	26.86	26.56	28.33	28.05	27.2	29.3	29.1	28.4	26.08	30.15	31.38	35.81
90	26.25	26.05	25.86	27.4	26.91	26.71	28.45	28.15	27.15	29.5	29.4	28.69	26.27	30.35	31.42	36.14
95	26.15	26.1	25.81	27.49	26.86	26.66	28.62	28.2	27.35	29.74	29.59	28.79	26.15	30.55	31.61	36.39
100	26.23	25.98	25.88	27.51	26.98	26.74	28.56	28.33	27.51	29.61	29.45	28.76	26.08	30.71	31.64	36.41
105	26.27	25.88	25.98	27.56	27.02	26.69	28.64	28.17	27.33	29.71	29.51	28.61	26.23	30.56	31.55	36.63
110	26.23	26.08	25.88	27.42	27.13	26.56	28.72	28.23	27.35	30.01	29.54	28.79	26.27	30.81	31.58	36.55
115	26.2	25.95	25.86	27.61	26.92	26.69	28.78	28.27	27.49	29.94	29.54	28.84	26.15	30.79	31.48	36.6
120	26.25	26.15	25.9	27.64	27	26.66	28.82	28.15	27.49	29.99	29.64	29.02	25.95	30.89	31.71	36.85

Table A4.1: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	26.27	26.12	25.92	27.54	27	26.81	28.73	28.3	27.49	29.91	29.54	28.99	26.08	31.01	31.61	37.09
130	26.35	26.1	25.92	27.61	27.02	26.84	28.85	28.27	27.54	30.08	29.74	29.08	26.02	31.15	31.76	37.03
135	26.35	26.2	25.95	27.51	27.02	26.84	28.75	28.23	27.54	29.99	29.74	29.02	26.12	31.2	31.58	36.92
140	26.39	26.3	25.95	27.66	26.98	26.69	28.86	28.27	27.64	30.05	30.01	29.25	26.08	31.23	31.74	37.09
145	26.39	26.2	25.84	27.46	27.08	26.74	28.76	28.27	27.49	30.05	29.74	28.96	26.02	31.33	31.79	37.19
150	26.44	26.05	26.1	27.64	27.05	26.84	28.94	28.4	27.61	30.23	29.89	29.23	25.95	31.3	31.86	37.16

Table A4.2: Experimental Data for Small Rashig Ring, $d_p = 3.27$ cm.
Run # 2: Re = 842.8 $Q_w = 243.4$ W/m^2 $T_{amb} = 25.5$ °C.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	24.925	25.08	24.98	25.13	25.17	25.23	25.13	25.44	25.64	25.69	25.64	25.51	24.54	25.69	25.41	25.56
5	24.925	24.79	24.92	25.23	25.02	25.17	25.37	25.27	25.46	25.51	25.66	25.46	24.71	25.76	26.2	27
10	24.975	24.83	24.83	25.33	25.17	25.17	25.59	25.56	25.54	25.84	25.79	25.59	25.15	26	27.44	28.3
15	24.925	25.02	24.83	25.66	25.33	25.17	25.89	25.81	25.56	26.12	26	25.61	25.17	26.27	28.17	29.64
20	25.125	25.02	24.92	25.88	25.66	25.27	26.19	26.17	25.76	26.49	26.39	25.86	25.17	26.49	29.13	30.71
25	25.225	25.17	24.98	26.2	25.76	25.36	26.48	26.3	25.81	26.76	26.51	26.17	25.27	26.91	29.59	31.66
30	25.388	25.27	25.08	26.46	25.92	25.69	26.83	26.69	26	27.2	27	26.1	25.25	27.25	30.3	32.58
35	25.388	25.35	25.1	26.64	26.08	25.59	27.13	26.89	26.27	27.61	27.46	26.46	25.36	27.66	30.61	33.38
40	25.413	25.33	25.27	26.71	26.17	25.81	27.38	27.23	26.25	28.05	27.76	26.81	25.46	27.91	30.99	33.96
45	25.487	25.39	25.25	26.84	26.49	25.88	27.57	27.44	26.49	28.3	28.08	27.17	25.44	28.25	31.38	34.79
50	25.462	25.51	25.33	27.05	26.41	26.12	27.91	27.61	26.69	28.76	28.35	27.49	25.35	28.76	31.6	35.24
55	25.687	25.49	25.25	27.13	26.54	26.08	28.00	27.79	26.71	28.86	28.56	27.66	25.66	29.08	31.96	35.99
60	25.638	25.69	25.44	27.35	26.79	26.27	28.26	27.89	26.86	29.17	28.99	27.81	25.46	29.5	32.06	36.31
65	25.612	25.56	25.23	27.37	26.76	26.2	28.39	28.05	26.92	29.4	28.94	28.27	25.69	29.76	32.13	36.7
70	25.638	25.64	25.41	27.46	26.86	26.41	28.56	28.02	27.08	29.66	29.3	28.45	25.49	29.96	32.17	36.78
75	25.687	25.59	25.44	27.42	26.92	26.33	28.62	28.13	27.2	29.81	29.48	28.4	25.66	30.17	32.25	37.09
80	25.763	25.66	25.44	27.64	26.89	26.35	28.79	28.2	27.35	29.94	29.71	28.71	25.81	30.59	32.47	37.16
85	25.837	25.64	25.49	27.64	26.89	26.54	28.87	28.3	27.33	30.1	29.66	28.94	25.74	30.84	32.55	37.36
90	25.638	25.69	25.54	27.54	26.89	26.49	28.94	28.3	27.33	30.33	29.81	29.13	25.69	30.89	32.81	37.78
95	25.875	25.74	25.59	27.69	27.13	26.64	29.02	28.45	27.42	30.35	30.05	28.84	25.74	31.08	32.96	38.28
100	25.862	25.81	25.51	27.76	27.05	26.61	29.07	28.51	27.4	30.38	30.01	29.15	25.49	31.35	32.91	38.44
105	25.737	25.64	25.64	27.84	27.08	26.54	29.29	28.74	27.49	30.74	30.08	29.1	25.71	31.58	33.04	38.56
110	25.763	25.61	25.41	27.76	27.1	26.61	29.25	28.56	27.59	30.74	30.27	29.27	25.71	31.84	32.89	38.69
115	25.788	25.74	25.51	27.91	27.27	26.71	29.35	28.74	27.54	30.79	30.27	29.66	25.71	31.79	33.14	38.84
120	25.812	25.76	25.56	27.91	27.1	26.51	29.40	28.71	27.74	30.89	30.25	29.54	25.44	31.96	33.06	38.81

Table A4.2: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	25.925	25.71	25.61	27.86	27.05	26.61	29.39	28.79	27.71	30.91	30.4	29.74	25.74	32.01	33.11	39.03
130	25.862	25.81	25.56	27.84	27.25	26.74	29.39	28.81	27.74	30.94	30.52	29.81	25.54	32.13	33.28	39.05
135	25.975	25.84	25.69	27.89	27.17	26.71	29.43	28.84	27.86	30.96	30.55	29.84	25.88	32.37	33.25	39.17
140	25.862	25.9	25.64	27.84	27.2	26.74	29.50	28.79	27.84	31.15	30.59	29.71	25.71	32.22	33.17	39.33
145	25.95	25.9	25.61	27.76	27.15	26.76	29.43	28.81	27.64	31.1	30.55	29.86	25.76	32.55	33.22	39.22
150	26	25.81	25.71	28	27.2	26.86	29.56	28.76	27.74	31.12	30.71	29.81	25.64	32.47	33.38	39.38
155	25.9	25.76	25.76	27.95	27.35	26.69	29.54	28.86	27.76	31.12	30.81	29.59	25.74	32.53	33.35	39.3
160	25.95	25.9	25.51	28	27.3	26.81	29.59	28.76	27.81	31.17	30.81	30.1	25.74	32.66	33.11	39.35
165	25.837	25.92	25.64	28.02	27.27	26.79	29.60	28.89	27.84	31.17	30.99	29.96	25.71	32.6	33.38	39.42
170	26	25.95	25.66	28.2	27.4	26.86	29.68	28.96	28	31.15	30.74	30.04	25.71	32.71	33.22	39.55

Table A4.3: Experimental Data for Small Rashig Ring, $d_p = 3.27$ cm.
Run # 3: Re = 606.8 $Q_w = 243.4\ W/m^2$ $T_{amb} = 25.0\ ^oC$.
Time in (minutes), Temperature in (^oC) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	$T_w 1$	$T_w 2$
0	24.98	25.02	25.02	24.87	24.98	25.08	25.23	25.27	25.66	25.71	25.81	25.98	25.23	26.12	25.17	25.61
5	25.13	24.95	25	25.17	25	24.95	25.44	25.27	25.56	25.71	25.61	25.76	25.36	26.33	26.51	26.95
10	25.08	25.13	25.08	25.41	25.36	25.13	25.63	25.61	25.54	25.84	25.88	25.84	25.25	26.44	27.79	28.54
15	25.08	25.17	25.08	25.76	25.56	25.23	25.97	25.86	25.84	26.17	26.38	26.02	25.33	26.56	28.94	29.86
20	25.35	25.3	25.25	26.2	25.79	25.54	26.38	26.15	25.79	26.56	26.56	26.02	25.17	26.74	29.86	31.15
25	25.59	25.3	25.15	26.54	26.12	25.64	26.73	26.54	25.98	26.91	26.95	26.33	25.33	27.23	30.84	32.28
30	25.44	25.44	25.13	26.79	26.23	25.88	27.12	26.98	26.1	27.44	27.35	26.54	25.02	27.49	31.45	33.42
35	25.46	25.41	25.23	27.13	26.51	25.88	27.51	27.33	26.3	27.89	27.79	26.89	25.35	27.89	32.01	34.38
40	25.54	25.39	25.15	27.4	26.69	25.98	27.90	27.64	26.64	28.4	28.3	27.23	25.35	28.4	32.66	35.25
45	25.66	25.51	25.27	27.56	26.98	26.23	28.18	27.98	26.61	28.79	28.74	27.56	25.33	28.69	33.01	36.16
50	25.56	25.51	25.36	27.71	26.95	26.35	28.48	28.25	26.84	29.25	29.25	27.89	25.39	29.2	33.35	36.78
55	25.51	25.46	25.41	27.81	27	26.3	28.79	28.48	27.02	29.76	29.45	28.02	25.39	29.61	33.76	37.36
60	25.54	25.44	25.25	28.02	27.17	26.51	29.01	28.64	27.2	29.99	29.79	28.33	25.41	29.89	33.89	38
65	25.76	25.41	25.36	27.98	27.17	26.46	29.18	28.74	27.4	30.38	30.08	28.86	25.44	30.48	34.25	38.51
70	25.71	25.61	25.36	28.2	27.25	26.74	29.45	28.96	27.49	30.69	30.38	29	25.2	30.59	34.45	39.25
75	25.66	25.46	25.33	28.25	27.4	26.64	29.57	29.13	27.51	30.89	30.79	29.35	25.1	31.2	34.6	39.5
80	25.56	25.56	25.36	28.27	27.51	26.81	29.74	29.23	27.61	31.2	30.79	29.35	25.2	31.45	34.6	39.89
85	25.49	25.54	25.35	28.45	27.54	26.74	29.99	29.3	27.74	31.52	31.25	29.71	25.3	31.79	34.94	40.3
90	25.76	25.51	25.41	28.42	27.54	26.86	30.08	29.48	27.91	31.74	31.27	29.89	25.13	32.11	35.11	40.7
95	25.74	25.44	25.35	28.54	27.59	26.89	30.25	29.54	27.98	31.96	31.6	29.86	25.05	32.33	35.4	41.01
100	25.59	25.64	25.3	28.49	27.54	26.89	30.30	29.61	27.91	32.11	31.74	30.3	25.27	32.47	35.4	41.34
105	25.64	25.59	25.35	28.59	27.64	26.98	30.42	29.76	28	32.25	31.84	30.4	25.13	32.76	35.42	41.6
110	25.66	25.36	25.27	28.56	27.46	26.86	30.49	29.74	28.23	32.42	31.91	30.52	25.35	33.06	35.5	41.78
115	25.54	25.54	25.44	28.59	27.59	26.79	30.57	29.71	28.13	32.55	32.13	30.74	25	33.28	35.63	41.95
120	25.69	25.49	25.35	28.64	27.61	27.08	30.67	29.96	28.23	32.69	32.33	30.86	25.23	33.47	35.6	42.16

Table A4.3: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	25.61	25.46	25.27	28.71	27.74	27	30.70	29.99	28.23	32.69	32.33	30.79	24.95	33.6	35.78	42.41
130	25.56	25.41	25.36	28.66	27.71	27.05	30.79	30.01	28.25	32.91	32.45	31.1	25.15	33.86	35.72	42.41
135	25.64	25.44	25.3	28.84	27.74	27.02	30.97	30.1	28.35	33.09	32.6	30.89	24.9	34.09	35.89	42.67
140	25.64	25.49	25.3	28.69	27.84	27.08	30.89	30.1	28.4	33.09	32.6	30.99	24.95	34.14	35.89	42.8
145	25.64	25.35	25.25	28.69	27.79	26.92	30.88	30.08	28.33	33.06	32.69	31.55	25.2	34.33	35.99	43.03
150	25.51	25.41	25.33	28.76	27.74	27.1	30.96	30.13	28.38	33.16	32.64	31.12	25.3	34.55	35.99	43.03
155	25.56	25.46	25.36	28.64	27.69	27.1	30.90	30.13	28.38	33.16	32.91	31.4	25.05	34.42	35.94	42.95
160	25.61	25.51	25.23	28.81	27.71	27.05	31.07	30.08	28.38	33.33	32.96	31.45	25.15	34.5	36.16	43.31
165	25.54	25.44	25.2	28.69	27.79	26.98	31.05	30.01	28.45	33.4	32.89	31.38	25.13	34.67	36.01	43.26
170	25.54	25.39	25.25	28.64	27.74	27.13	31.00	30.23	28.59	33.35	33.04	31.48	25.05	34.81	36.01	43.49
175	25.61	25.46	25.27	28.76	27.74	27.2	31.08	30.27	28.3	33.4	33.04	31.58	24.98	34.94	36.19	43.39
180	25.54	25.39	25.2	28.84	27.74	27.08	31.06	30.33	28.64	33.28	33.01	31.58	25	34.91	36.11	43.54
185	25.54	25.49	25.2	28.79	27.81	26.98	31.02	30.38	28.48	33.25	33.04	31.6	25.13	35.01	36.14	43.51
190	25.51	25.36	25.41	28.76	27.74	27	31.12	30.13	28.51	33.47	33.11	31.91	25.08	35.19	36.19	43.58
195	25.44	25.44	25.35	28.84	27.84	27.08	31.15	30.38	28.61	33.45	33.04	31.79	24.87	35.21	36.24	43.67
200	25.46	25.41	25.13	28.76	27.86	27.05	31.21	30.35	28.51	33.65	33.06	31.71	24.85	35.24	36.04	43.75
205	25.46	25.33	25.23	28.76	27.71	27.1	31.25	30.4	28.48	33.74	33.2	31.81	25.2	35.33	36.21	43.8

Table A4.4: Experimental Data for Small Rashig Ring, $d_p = 3.27$ cm.
Run # 4: Re = 342.0 $Q_w = 243.4\ W/m^2$ $T_{amb} = 25.0\ ^oC$.
Time in (minutes), Temperature in (^{o}C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	24.337	24.3	24.54	24.64	24.64	24.87	25	25.15	25.39	25.64	25.54	25.64	24.15	25.69	24.79	25.59
5	24.25	24.49	24.49	24.66	24.71	24.9	25.14	24.95	25.36	25.61	25.61	25.66	24.27	25.76	26	26.91
10	24.2	24.15	24.34	24.9	24.69	24.85	25.30	25.15	25.25	25.69	25.79	25.44	24.2	25.84	27.86	28.51
15	24.362	24.51	24.36	25.25	24.9	24.71	25.68	25.66	25.46	26.1	26.05	25.71	24.36	26.05	29.35	30.1
20	24.388	24.39	24.39	25.69	25.35	24.85	25.98	25.69	25.33	26.27	26.38	25.61	24.1	26.17	30.59	31.58
25	24.538	24.39	24.34	26.12	25.64	25.02	26.38	26.27	25.54	26.64	26.74	26.02	24.34	26.59	31.64	33.01
30	24.638	24.59	24.34	26.61	25.81	25.13	26.86	26.61	25.51	27.1	27.05	26.2	24.13	26.76	32.86	34.4
35	24.813	24.56	24.27	27.15	26.1	25.27	27.38	26.95	25.86	27.61	27.61	26.46	24.3	27.33	33.62	35.78
40	24.975	24.79	24.54	27.49	26.56	25.49	27.86	27.42	26.02	28.23	27.94	26.61	24.59	27.59	34.65	36.92
45	24.925	24.83	24.54	27.79	26.89	25.69	28.28	27.89	26.15	28.76	28.38	26.81	24.31	28	35.47	37.97
50	24.975	24.87	24.49	28.17	26.98	25.92	28.72	28.33	26.3	29.27	28.81	27.13	24.71	28.3	36.16	39.13
55	25.2	24.98	24.49	28.54	27.33	26.12	29.20	28.69	26.56	29.86	29.4	27.61	24.54	28.94	36.72	39.94
60	25.225	25.17	24.69	28.84	27.56	26.15	29.62	28.99	26.81	30.4	29.89	27.95	24.51	29.42	37.31	40.83
65	25.462	25.33	24.61	29.08	27.71	26.3	29.97	29.5	27.15	30.86	30.5	28.4	24.61	29.84	37.78	41.7
70	25.362	25.17	24.74	29.45	27.94	26.56	30.44	29.69	27.25	31.42	30.91	28.64	24.56	30.17	38.39	42.62
75	25.513	25.35	24.85	29.51	28.15	26.79	30.75	30.08	27.42	31.99	31.35	29.17	24.79	30.66	38.76	43.16
80	25.763	25.41	24.87	29.74	28.23	26.81	31.05	30.42	27.69	32.35	31.61	29.61	24.95	31.1	39.33	43.95
85	25.737	25.33	24.83	29.96	28.49	27.13	31.38	30.56	27.89	32.79	31.99	29.89	25.05	31.33	39.45	44.67
90	25.687	25.59	25	30.27	28.59	27.3	31.79	30.96	28.1	33.3	32.47	30.13	25	31.79	39.76	45.34
95	25.925	25.49	25.1	30.48	28.84	27.37	32.10	31.15	28.35	33.71	32.81	30.55	25	32.4	40.37	45.72
100	26.05	25.59	25.05	30.35	29	27.54	32.26	31.42	28.35	34.16	33.11	30.76	25.1	32.74	40.5	46.19
105	26	25.51	24.95	30.59	29.23	27.54	32.56	31.64	28.71	34.53	33.58	31.27	24.85	33.2	40.8	46.72
110	25.862	25.66	25.27	30.61	29.23	27.56	32.68	31.79	29	34.74	33.94	31.52	25.05	33.53	40.83	46.95
115	25.95	25.81	25.23	30.76	29.27	27.81	33.01	32.01	28.84	35.25	34.22	31.76	24.79	33.86	40.83	47.41
120	26.175	25.69	25.25	31.01	29.45	27.94	33.28	32.17	29	35.55	34.65	32.11	25.08	34.33	41.11	47.78

Table A4.4: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	26.15	25.79	25.25	31.06	29.48	27.98	33.42	32.35	29.23	35.78	34.81	32.22	25.08	34.65	41.41	47.97
130	26.15	25.9	25.33	31.23	29.64	28.1	33.65	32.58	29.54	36.06	34.99	32.71	24.74	34.99	41.44	48.39
135	26.2	25.98	25.3	31.15	29.66	28.2	33.70	32.63	29.56	36.24	35.38	32.71	24.71	35.33	41.5	48.72
140	26.15	25.95	25.39	31.25	29.66	28.35	33.95	32.76	29.61	36.65	35.42	33.04	24.66	35.53	41.65	48.99
145	26.25	26	25.27	31.38	29.84	28.4	34.05	32.84	29.91	36.72	35.7	33.35	24.95	35.96	41.92	49.29
150	26.275	25.84	25.39	31.4	29.76	28.4	34.22	32.96	30.01	37.03	35.89	33.45	24.98	36.21	41.9	49.45
155	26.175	25.95	25.41	31.5	29.89	28.38	34.36	33.06	30.01	37.21	36.11	33.45	24.9	36.45	41.8	49.72
160	26.3	25.88	25.54	31.4	29.96	28.49	34.38	33.14	30.1	37.36	36.34	33.71	24.95	36.7	42.01	50.06
165	26.25	26	25.39	31.52	29.99	28.49	34.49	33.3	30.27	37.46	36.39	34.09	24.69	37.14	42.24	50.06
170	26.25	25.9	25.46	31.52	30.04	28.54	34.61	33.45	30.38	37.69	36.53	34.22	24.87	37.24	42.06	50.22
175	26.275	26.08	25.44	31.58	30.01	28.69	34.83	33.45	30.25	38.08	36.92	34.33	24.64	37.51	42.11	50.54
180	26.225	25.84	25.39	31.66	30.13	28.64	34.81	33.45	30.52	37.95	36.7	34.45	24.79	37.46	42.29	50.54
185	26.275	26.02	25.49	31.61	30.17	28.59	34.78	33.69	30.52	37.95	36.92	34.55	25.02	37.72	42.24	50.64
190	26.275	25.81	25.51	31.6	30.15	28.66	34.85	33.65	30.64	38.1	37	34.63	24.85	38.05	42.26	50.81
195	26.325	25.86	25.46	31.79	30.1	28.66	35.04	33.74	30.59	38.28	37.34	34.74	24.95	38.28	42.26	51.05
200	26.2	25.95	25.39	31.58	30.13	28.64	35.02	33.71	30.64	38.46	37.21	34.84	24.95	38.41	42.31	50.92
205	26.388	25.98	25.54	31.76	30.13	28.64	35.18	33.67	30.69	38.59	37.41	35.09	24.85	38.51	42.31	51.15
210	26.2	26.1	25.54	31.76	30.27	28.79	35.31	33.94	30.89	38.86	37.7	35.21	24.95	38.69	42.39	51.34
215	26.25	25.95	25.46	31.69	30.2	28.66	35.20	33.94	30.76	38.71	37.72	35.14	24.83	39.05	42.62	51.36
220	26.3	25.88	25.54	31.71	30.13	28.79	35.31	33.91	30.79	38.91	37.54	35.35	24.87	38.95	42.54	51.39
225	26.3	25.84	25.64	31.76	30.23	28.84	35.34	34.09	30.89	38.91	37.92	35.42	25	39.25	42.54	51.46
230	26.375	25.92	25.54	31.81	30.33	28.89	35.42	34.09	30.94	39.03	37.88	35.84	24.71	39.42	42.65	51.75
235	26.413	26.12	25.59	31.91	30.2	28.89	35.50	33.74	30.99	39.08	37.9	35.47	24.59	39.58	42.54	51.64
240	26.275	25.95	25.46	31.91	30.25	28.84	35.52	33.91	30.99	39.13	38.03	35.63	24.98	39.58	42.7	51.75
245	26.325	25.98	25.54	31.81	30.27	28.79	35.51	34.19	31.1	39.2	38.15	35.91	24.71	39.71	42.67	51.9

Table A4.5: Experimental Data for Small Rashig Ring, $d_p = 3.27$ cm.
Run # 5: Re = 1035.5 $Q_w = 179.2\ W/m^2$ $T_{amb} = 25.8\ ^oC$.
Time in (minutes), Temperature in (^oC) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	25.513	25.36	25.56	25.61	25.81	26.08	26.02	25.9	26.38	26.41	26.46	26.51	25.33	26.56	25.76	26.38
5	25.413	25.41	25.46	25.71	25.66	25.76	26.05	25.76	26.2	26.39	26.39	26.1	25.56	26.54	26.49	27.3
10	25.612	25.44	25.44	25.86	25.61	25.66	26.14	26.05	26.23	26.41	26.56	26.41	25.69	26.61	27.08	28.08
15	25.663	25.41	25.51	25.92	25.76	25.71	26.32	26.12	26.17	26.71	26.46	26.41	25.92	26.71	27.66	28.89
20	25.638	25.64	25.49	26.2	25.88	25.84	26.47	26.3	26.23	26.74	26.92	26.38	25.74	26.98	28.17	29.5
25	25.812	25.71	25.61	26.35	26	25.81	26.67	26.39	26.2	26.98	26.84	26.49	25.88	27.23	28.4	30.05
30	25.862	25.81	25.71	26.56	26.08	25.92	26.92	26.51	26.33	27.27	27.13	26.69	25.84	27.37	28.84	30.61
35	25.837	25.79	25.59	26.64	26.2	25.98	27.02	26.79	26.49	27.4	27.3	26.86	26.35	27.71	29.05	31.33
40	25.95	25.9	25.76	26.81	26.44	26.3	27.24	27	26.61	27.66	27.46	27.15	26.41	27.91	29.38	31.42
45	25.925	26.02	25.84	26.89	26.54	26.3	27.30	27.17	26.71	27.71	27.91	27.15	26.41	28.15	29.48	31.89
50	26.05	26.1	25.95	27	26.64	26.35	27.48	27.15	26.86	27.95	27.81	27.37	26.12	28.27	29.59	32.2
55	26.05	26.05	26	27	26.66	26.3	27.57	27.35	26.92	28.13	28.02	27.61	26.33	28.56	29.64	32.53
60	26.2	26.33	26	27.1	26.71	26.51	27.59	27.4	27.02	28.08	28.23	27.61	26.27	28.84	29.91	32.84
65	26.388	26.2	26.05	27.13	26.84	26.59	27.86	27.44	26.95	28.59	28.15	27.49	26.2	28.86	29.96	32.86
70	26.275	26.27	26.17	27.37	26.89	26.61	28.06	27.66	27.15	28.74	28.35	27.84	26.35	29	30.23	33.17
75	26.35	26.25	26.2	27.3	26.89	26.64	27.96	27.74	27.2	28.61	28.56	28	26.38	29.23	30.23	33.4
80	26.413	26.41	26.27	27.51	26.86	26.71	28.20	27.81	27.37	28.89	28.59	27.94	26.3	29.35	30.2	33.47
85	26.462	26.27	26.27	27.42	27.08	26.71	28.16	27.66	27.33	28.89	28.66	28.08	26.66	29.5	30.4	33.81
90	26.375	26.46	26.41	27.42	27.15	26.91	28.25	27.76	27.27	29.08	28.84	28.13	26.41	29.69	30.4	34.09
95	26.487	26.44	26.39	27.69	27.1	26.86	28.37	27.86	27.44	29.05	28.96	28.54	26.46	29.56	30.27	33.86
100	26.562	26.46	26.38	27.56	27.15	26.81	28.40	27.81	27.35	29.23	29	28.4	26.41	29.94	30.69	34.28
105	26.538	26.44	26.38	27.51	27.17	26.79	28.34	27.94	27.27	29.17	29.08	28.48	26.54	29.84	30.61	34.16
110	26.638	26.59	26.25	27.49	27.1	26.84	28.40	27.98	27.54	29.3	29.2	28.54	26.54	30.01	30.48	34.38
115	26.413	26.51	26.33	27.66	27.25	26.91	28.52	28	27.56	29.38	29	28.56	26.23	30.17	30.64	34.45
120	26.375	26.41	26.17	27.51	27.05	26.91	28.42	28.1	27.66	29.33	29.23	28.66	26.27	30.23	30.59	34.45

Table A4.5: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	26.388	26.44	26.17	27.64	27.17	26.89	28.62	28.13	27.66	29.59	29.17	28.56	26.33	30.3	30.71	34.67
130	26.413	26.33	26.33	27.51	27.13	26.89	28.48	27.94	27.66	29.45	29.23	28.79	26.27	30.2	30.5	34.58
135	26.413	26.46	26.35	27.59	27.15	26.76	28.51	28.05	27.49	29.42	29.3	28.71	26.41	30.27	30.48	34.55
140	26.513	26.46	26.27	27.61	27.15	26.95	28.55	28.15	27.61	29.48	29.15	28.96	26.27	30.48	30.64	34.74
145	26.325	26.33	26.41	27.51	27.1	26.91	28.54	28.05	27.46	29.56	29.27	28.38	26.41	30.45	30.64	34.86
150	26.462	26.39	26.15	27.54	27.1	27	28.51	28.05	27.59	29.48	29.2	28.76	26.56	30.59	30.64	34.42

Table A4.6: Experimental Data for Small Rashig Ring, d_p = 3.27 cm.
Run # 6: Re = 842.8 Q_w = 179.2 W/m^2 T_{amb} = 26.5 °C.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	25.49	25.39	25.49	25.54	25.59	25.69	25.79	25.74	26.08	26.17	26.08	26.17	25.49	26.44	26.08	26.49
5	25.79	25.59	25.59	25.98	25.84	25.79	26.02	26.02	26.08	26.38	26.27	26.33	26.12	26.51	26.98	27.51
10	26.1	25.9	25.66	26.39	26	25.86	26.54	26.25	26.38	27.05	27.05	26.46	26.23	27.05	28	28.71
15	26.33	26.08	25.84	26.86	26.23	26.23	27	26.51	26.41	27.51	27.37	26.76	26.56	27.33	28.71	29.84
20	26.59	26.25	26.15	27.4	26.39	26.44	27.44	26.92	26.69	28.15	27.64	27.05	26.59	27.84	29.45	30.89
25	26.66	26.33	26.17	27.51	26.71	26.38	27.71	27.08	26.69	28.45	28.02	27.35	26.59	28.25	29.86	31.79
30	26.74	26.54	26.25	27.84	26.84	26.59	28.13	27.2	26.95	28.86	28.4	27.59	26.51	28.54	30.27	32.6
35	26.91	26.61	26.23	27.95	26.86	26.61	28.25	27.3	26.95	29.45	28.59	27.54	26.61	28.96	30.56	33.25
40	26.86	26.61	26.33	28.15	26.81	26.71	28.35	27.4	27.02	29.42	28.86	27.61	26.84	29.17	30.79	33.84
45	26.89	26.64	26.54	28.17	27.08	26.64	28.51	27.69	27.13	29.56	28.91	27.86	26.84	29.51	31.15	34.25
50	27.02	26.49	26.44	28.27	27.02	26.69	28.64	27.54	27.2	30.01	29.15	28.15	26.56	29.64	31.33	34.65
55	27.13	26.59	26.3	28.38	27.08	26.59	28.66	27.56	27.25	30.01	29.1	27.91	26.81	29.96	31.35	34.99
60	27.13	26.64	26.59	28.42	27.23	26.69	28.81	27.71	27.17	30.27	29.33	28.08	26.98	30.23	31.71	35.47
65	26.98	26.69	26.39	28.56	27.27	26.84	29	27.81	27.23	30.27	29.48	28.05	26.76	30.48	31.76	35.78
70	27.08	26.79	26.49	28.56	27.33	26.79	28.86	27.86	27.3	30.42	29.56	28.05	26.56	30.48	31.91	36.04
75	27.2	26.71	26.38	28.59	27.35	26.76	28.84	27.84	27.25	30.48	29.4	28.15	26.51	30.56	31.84	36.09
80	27.17	26.64	26.44	28.66	27.23	26.84	29.1	27.86	27.37	30.52	29.66	28.48	26.64	30.74	31.91	36.53
85	27.02	26.71	26.46	28.76	27.37	26.76	29.15	27.95	27.37	30.64	29.74	28.27	26.79	30.74	31.91	36.53
90	27.17	26.69	26.44	28.91	27.33	26.89	29.15	28	27.33	30.84	29.71	28.2	26.79	31.04	32.2	36.9
95	27.13	26.84	26.49	28.91	27.33	26.92	29.1	28.1	27.44	30.76	29.74	28.33	26.91	30.96	32.13	36.92
100	27.3	26.76	26.38	28.74	27.3	26.81	29.27	27.98	27.42	30.94	29.86	28.45	26.76	31.12	32.4	36.95
105	27.25	26.66	26.51	28.79	27.44	26.86	29.27	28.13	27.54	31.01	29.89	28.59	26.66	31.25	32.22	37.03
110	27.3	26.61	26.66	28.79	27.3	26.86	29.25	28.15	27.49	30.91	29.86	28.59	26.91	31.23	32.3	37.14
115	27.2	26.59	26.54	28.76	27.4	26.92	29.38	28.13	27.51	30.89	30.01	28.61	26.89	31.33	32.37	37.31
120	27.17	26.69	26.49	29.02	27.4	26.79	29.13	28.08	27.44	31.08	29.91	28.49	26.86	31.33	32.45	37.24

Table A4.6: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	27.35	26.81	26.61	28.89	27.59	26.86	29.33	28.08	27.56	31.12	29.96	28.45	26.81	31.38	32.35	37.36
130	27.33	26.79	26.59	29	27.51	26.98	29.4	28.05	27.54	31.15	30.04	28.42	26.91	31.52	32.28	37.49
135	27.3	26.86	26.61	28.99	27.54	26.95	29.42	28.13	27.59	31.2	29.89	28.74	26.86	31.48	32.5	37.66
140	27.33	26.89	26.74	29.05	27.61	26.98	29.45	28.25	27.56	31.17	30.08	28.66	27.02	31.55	32.47	37.64
145	27.4	26.91	26.61	28.99	27.64	27	29.51	28.13	27.74	31.1	30.13	28.48	26.71	31.71	32.47	37.59
150	27.35	26.76	26.71	29.02	27.74	27.05	29.51	28.08	27.59	31.4	30.13	28.56	27.02	31.6	32.58	37.72
155	27.25	26.81	26.51	29.02	27.44	26.81	29.38	28.1	27.56	31.2	30.25	28.49	26.56	31.61	32.45	37.83
160	27.15	26.66	26.41	29.02	27.4	27	29.4	28.15	27.51	31.17	30.1	28.56	26.69	31.74	32.58	37.95

Table A4.7: Experimental Data for Small Rashig Ring, $d_p = 3.27$ cm.
Run # 7: Re = 606.8 $Q_w = 179.2$ W/m^2 $T_{amb} = 27.8$ °C.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	27.37	27.27	27.33	27.37	27.37	27.51	27.76	27.61	27.95	27.95	28	27.95	26.86	28	27.56	27.86
5	27.13	27.17	27.08	27.33	27.37	27.37	27.68	27.51	27.81	28.02	27.91	27.86	27.08	28.08	28.33	28.96
10	27.15	27.05	27.2	27.64	27.49	27.4	27.83	27.81	27.79	28.02	28.25	28.02	27.1	28.08	29.4	29.91
15	27.08	27.08	27.08	27.74	27.49	27.49	28.01	27.94	27.94	28.27	28.42	28.13	27.33	28.38	30.25	31.06
20	27.15	27.1	27	27.89	27.64	27.44	28.24	28.15	27.98	28.59	28.59	28.08	27.4	28.59	30.76	31.84
25	27.17	27.13	27.02	28.08	27.84	27.56	28.42	28.23	27.95	28.76	28.86	28.27	27.37	28.81	31.3	32.64
30	27.33	27.17	27.23	28.33	27.95	27.76	28.60	28.56	28.05	28.86	28.96	28.51	27.37	29.05	31.79	33.4
35	27.13	27.23	27.17	28.51	28.15	27.71	28.93	28.76	28.05	29.35	29.3	28.59	27.4	29.4	32.35	34.04
40	27.27	27.33	27.23	28.86	28.25	27.71	29.26	29	28.25	29.66	29.66	28.81	27.42	29.61	32.63	34.7
45	27.42	27.33	27.27	29.13	28.38	27.98	29.62	29.23	28.49	30.1	29.81	29	27.37	29.91	32.94	35.45
50	27.49	27.3	27.25	28.99	28.4	27.94	29.66	29.3	28.48	30.33	30.17	29.17	27.66	30.13	33.3	35.81
55	27.51	27.37	27.37	29.27	28.51	27.91	29.81	29.48	28.64	30.35	30.4	29.35	27.4	30.45	33.6	36.24
60	27.44	27.44	27.3	29.23	28.59	28.08	30.02	29.74	28.86	30.81	30.81	29.81	27.56	30.71	33.74	36.55
65	27.56	27.37	27.51	29.42	28.76	28.33	30.24	29.91	28.74	31.06	30.89	29.99	27.49	31.06	33.99	37.29
70	27.66	27.44	27.2	29.5	28.86	28.3	30.31	29.96	28.96	31.12	31.04	30.23	27.56	31.45	34.19	37.54
75	27.71	27.66	27.46	29.54	28.86	28.35	30.51	30.01	29.1	31.48	31.33	30.2	27.51	31.48	34.28	37.88
80	27.66	27.61	27.46	29.61	29	28.45	30.73	30.27	29.15	31.84	31.48	30.4	27.66	31.69	34.42	38.15
85	27.59	27.64	27.35	29.74	29.15	28.45	30.78	30.3	29.2	31.81	31.71	30.59	27.59	32.04	34.58	38.41
90	27.74	27.69	27.59	29.89	29.15	28.49	30.95	30.35	29.23	32.01	31.96	30.64	27.59	32.33	34.6	38.71
95	27.74	27.59	27.49	29.79	29.08	28.59	31.02	30.5	29.42	32.25	32.11	30.84	27.71	32.47	34.84	38.81
100	27.79	27.84	27.51	29.86	29.23	28.51	31.18	30.42	29.45	32.5	32.22	31.15	27.54	32.64	34.89	39
105	27.74	27.74	27.54	29.94	29.17	28.69	31.15	30.64	29.4	32.35	32.25	31.27	27.71	32.71	35.11	39.22
110	27.81	27.81	27.66	30.01	29.25	28.74	31.31	30.71	29.45	32.6	32.25	31.33	27.81	33.01	35.21	39.61
115	27.84	27.79	27.64	30.08	29.27	28.66	31.49	30.69	29.64	32.89	32.33	31.3	27.64	33.2	35.06	39.64
120	28	27.86	27.71	29.96	29.4	28.66	31.41	30.91	29.61	32.86	32.55	31.42	27.81	33.33	35.3	39.89

Table A4.7: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	27.94	27.79	27.59	30.04	29.35	28.79	31.47	30.91	29.74	32.89	32.6	31.58	27.81	33.53	35.35	40.09
130	27.98	27.94	27.64	30.23	29.42	28.71	31.57	30.99	29.81	32.91	32.86	31.52	27.71	33.47	35.25	40.11
135	27.98	27.84	27.74	30.13	29.5	28.79	31.68	31.06	29.84	33.22	32.89	31.69	27.89	33.76	35.6	40.22
140	27.89	27.98	27.74	30.13	29.42	28.84	31.65	30.94	29.81	33.17	32.81	31.89	27.76	33.84	35.53	40.25
145	27.91	27.86	27.66	30.25	29.5	28.86	31.75	31.06	29.89	33.25	33.06	31.91	27.81	34.04	35.55	40.4
150	28.02	27.84	27.74	30.17	29.42	28.84	31.78	30.99	29.74	33.38	33.01	31.81	27.81	34.04	35.72	40.47
155	28.05	27.91	27.71	30.25	29.56	29	31.83	31.33	30.04	33.4	33.14	32.06	27.89	34.19	35.7	40.78
160	28.1	28	27.76	30.4	29.64	29.05	32.03	31.01	30.01	33.65	33.17	32.09	27.94	34.3	35.63	40.75
165	28	27.95	27.81	30.35	29.5	29	31.93	31.33	29.96	33.5	33.22	32.25	27.94	34.42	35.84	40.86
170	28.05	28	27.76	30.4	29.54	29.08	31.98	31.3	30.13	33.55	33.3	32.11	27.76	34.45	35.7	40.99
175	28.13	27.98	27.79	30.52	29.61	29	32.11	31.27	30.15	33.69	33.42	32.25	27.94	34.58	35.78	41.01
180	28.17	27.98	27.74	30.33	29.61	28.91	31.94	31.38	30.17	33.55	33.33	32.3	27.98	34.74	35.67	41.09
185	28.02	28.02	27.89	30.59	29.59	29.02	32.17	31.45	29.99	33.74	33.28	32.42	27.69	34.79	35.84	40.99
190	28.17	27.98	27.84	30.56	29.56	29	32.23	31.48	30.17	33.89	33.42	32.5	27.89	34.89	35.89	40.96
195	28.08	28.08	27.84	30.52	29.71	29.17	32.16	31.48	30.13	33.79	33.38	32.45	27.84	34.74	35.99	41.19
200	28.2	28.1	27.81	30.45	29.69	29.17	32.21	31.5	29.99	33.96	33.6	32.58	27.86	34.96	35.89	41.26
205	28.13	27.94	27.94	30.56	29.66	29	32.28	31.52	30.33	33.99	33.58	32.45	28.02	34.99	36.04	41.5
210	28.17	27.91	27.91	30.48	29.76	29.1	32.21	31.48	30.2	33.94	33.71	32.5	27.91	35.14	35.91	41.34
215	28.1	28.02	27.84	30.33	29.74	29.13	32.09	31.45	30.17	33.84	33.6	32.76	27.94	35.16	35.89	41.41
220	28.1	28.05	27.91	30.55	29.89	28.96	32.26	31.58	30.3	33.96	33.71	32.74	27.95	35.11	36.11	41.39
225	28.17	28.13	27.89	30.61	29.66	29.17	32.33	31.48	30.25	34.04	33.67	32.64	27.84	35.14	35.91	41.5
230	28.2	28.15	27.98	30.59	29.84	29.17	32.35	31.6	30.33	34.11	33.74	32.71	27.98	35.21	36.21	41.55
235	28.3	28.1	27.95	30.45	29.74	29.3	32.28	31.66	30.42	34.11	33.69	32.66	27.84	35.25	35.89	41.41
240	28.17	28.08	27.94	30.66	29.94	29.23	32.38	31.55	30.25	34.09	33.71	32.64	27.95	35.33	36.01	41.53
245	28.25	28.05	27.91	30.5	29.84	29.27	32.27	31.6	30.45	34.04	33.76	32.79	28	35.33	35.86	41.39
250	28.2	28.15	27.91	30.55	29.74	29.25	32.28	31.52	30.4	34.01	33.81	32.89	27.91	35.42	35.94	41.53
255	28.15	28.08	27.89	30.55	29.79	29.17	32.30	31.5	30.4	34.04	33.76	32.79	27.81	35.38	36.01	41.53
260	28.2	28.05	27.91	30.59	29.94	29.27	32.39	31.5	30.52	34.19	33.76	32.86	27.84	35.55	36.14	41.47

Table A4.8: Experimental Data for Small Rashig Ring, $d_p = 3.27$ cm.
Run # 8: Re = 342.0 $Q_w = 179.2$ W/m^2 $T_{amb} = 27.5$ °C.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	26.84	26.74	26.89	27.02	26.92	27.02	27.17	27.17	27.56	27.61	27.71	27.66	26.41	27.86	26.92	27.61
5	26.74	26.84	26.74	26.89	26.92	26.84	27.35	27.1	27.46	27.81	27.71	27.91	26.66	27.81	28	28.76
10	26.86	26.81	26.76	27.02	26.92	27.02	27.31	27.27	27.49	27.59	27.74	27.79	26.86	27.89	29.1	29.54
15	26.86	26.76	26.91	27.35	27.25	27.1	27.62	27.61	27.42	27.89	27.89	27.76	27.08	28.13	30.13	30.86
20	26.81	26.91	26.76	27.95	27.4	26.95	28.04	27.74	27.54	28.13	28.23	27.89	26.98	28.23	31.33	32.04
25	26.98	26.92	26.79	28.02	27.59	27.1	28.25	28.13	27.51	28.48	28.48	27.91	26.98	28.38	32.13	32.86
30	27.17	27.08	26.76	28.38	27.95	27.33	28.59	28.33	27.64	28.79	28.79	28.15	27.1	28.64	32.79	33.86
35	27.25	27.05	26.91	28.69	28.05	27.49	28.93	28.69	27.89	29.17	29.02	28.38	27.08	28.79	33.45	34.74
40	27.27	27.13	26.98	29.23	28.38	27.61	29.37	28.96	27.95	29.5	29.4	28.49	26.91	29.2	34.25	35.53
45	27.27	27.17	27.02	29.33	28.64	27.74	29.69	29.27	28.02	30.04	29.79	28.79	27.23	29.48	34.7	36.55
50	27.44	27.4	27.05	29.54	28.74	27.94	30.02	29.54	28.23	30.5	29.99	28.84	27.08	29.69	35.19	37.26
55	27.49	27.25	27.2	29.71	29.15	28.05	30.24	29.86	28.49	30.76	30.35	29.13	26.92	30.05	35.55	38.03
60	27.51	27.35	27	30.13	29	28.1	30.63	30.23	28.81	31.12	30.84	29.42	27.2	30.52	35.99	38.36
65	27.61	27.56	27	30.05	29.25	28.2	30.79	30.33	28.76	31.52	31.2	30.04	26.79	30.74	36.44	39.1
70	27.66	27.33	27.08	30.17	29.48	28.33	31.04	30.55	28.91	31.91	31.45	29.99	26.98	31.01	36.7	39.81
75	27.51	27.37	27.08	30.33	29.56	28.56	31.25	30.74	29.08	32.17	31.79	30.15	26.89	31.27	36.83	40.16
80	27.74	27.46	27.02	30.5	29.79	28.61	31.54	31.01	29.17	32.58	32.15	30.3	26.91	31.58	37.16	40.78
85	27.54	27.54	27.2	30.61	29.71	28.86	31.80	31.23	29.51	32.99	32.37	30.99	26.81	31.91	37.39	41.14
90	27.81	27.66	27.15	30.99	29.96	28.86	32.15	31.45	29.48	33.3	32.6	30.89	26.89	32.17	37.78	41.7
95	27.79	27.59	27.15	30.91	29.91	28.99	32.23	31.55	29.69	33.55	32.91	31.06	26.86	32.35	37.92	42.04
100	27.69	27.49	27.15	31.08	30.15	28.94	32.42	31.74	29.71	33.76	33.09	31.55	26.91	32.71	38.1	42.26
105	27.89	27.49	27.3	31.12	30.05	28.94	32.49	31.74	29.81	33.86	33.14	31.6	27	32.94	38.1	42.26
110	27.74	27.59	27.25	31.12	30.15	29.1	32.62	31.96	30.04	34.11	33.47	31.66	26.79	33.2	38.28	42.75
115	27.69	27.59	27.35	31.17	30.15	29.25	32.80	32.15	29.99	34.42	33.67	32.17	27.02	33.42	38.33	42.85
120	27.79	27.74	27.33	31.27	30.35	29.27	32.96	32.13	30.15	34.65	33.91	32.11	26.95	33.76	38.41	43.16

Table A4.8: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	27.76	27.56	27.17	31.25	30.17	29.27	33.01	32.22	30.1	34.76	34.19	32.42	27	33.91	38.46	43.34
130	27.84	27.54	27.44	31.27	30.45	29.13	33.09	32.4	30.42	34.91	34.35	32.37	26.95	34.19	38.74	43.72
135	27.86	27.61	27.3	31.55	30.38	29.3	33.31	32.47	30.59	35.06	34.47	32.91	27.02	34.42	38.89	43.92
140	27.95	27.66	27.27	31.4	30.59	29.33	33.37	32.5	30.5	35.33	34.65	33.17	27.13	34.74	38.71	44.34
145	27.84	27.69	27.13	31.58	30.4	29.42	33.54	32.6	30.52	35.5	34.76	33.16	26.81	34.76	38.69	44.24
150	27.81	27.71	27.23	31.55	30.38	29.42	33.60	32.79	30.66	35.65	34.96	33.4	27.05	35.24	39.05	44.46
155	27.84	27.64	27.2	31.5	30.52	29.4	33.65	32.66	30.69	35.8	35.01	33.38	27.1	35.16	39.1	44.56
160	27.89	27.61	27.42	31.48	30.5	29.48	33.72	32.86	30.81	35.96	35.28	33.69	27.1	35.45	39.17	44.9
165	27.94	27.74	27.35	31.69	30.55	29.45	33.93	32.91	30.94	36.16	35.21	33.53	27.17	35.72	39.17	45.1
170	27.95	27.71	27.4	31.86	30.66	29.61	34.08	32.94	30.96	36.29	35.47	33.74	27.02	35.84	39.47	45.29
175	27.86	27.81	27.35	31.74	30.61	29.45	33.98	33.04	30.96	36.21	35.63	33.74	26.92	35.94	39.25	45.41
180	27.95	27.76	27.27	31.76	30.74	29.66	34.09	33.06	30.96	36.41	35.7	34.06	27.05	36.14	39.5	45.41
185	28.08	27.64	27.33	31.84	30.76	29.74	34.19	33.22	31.04	36.53	35.72	33.99	27	36.36	39.61	45.56
190	28.05	27.71	27.37	31.91	30.89	29.61	34.23	33.25	31.01	36.55	35.8	34.16	27.2	36.55	39.64	45.8
195	27.94	27.94	27.33	31.86	30.74	29.74	34.35	33.28	31.04	36.83	36.04	34.28	27.1	36.67	39.61	45.83
200	28.05	27.71	27.51	31.86	30.79	29.56	34.32	33.4	31.33	36.78	35.96	34.28	27.2	36.88	39.64	45.92
205	28.08	27.76	27.46	31.91	30.84	29.89	34.42	33.38	31.33	36.92	36.19	34.47	27.3	36.88	39.76	46.21
210	28.08	27.89	27.51	32.04	30.89	29.79	34.52	33.58	31.3	37	36.14	34.5	27.46	37.05	39.66	46.21
215	28.2	27.81	27.51	32.01	30.99	29.86	34.38	33.53	31.38	36.75	36.34	34.58	27.15	37.29	39.96	46.36
220	28.1	27.71	27.46	31.96	30.94	29.76	34.53	33.47	31.38	37.09	36.29	34.65	27.27	37.36	39.99	46.34
225	28.23	27.98	27.4	32.09	31.01	29.89	34.65	33.65	31.25	37.21	36.36	34.4	27.13	37.61	40.06	46.64
230	28.13	27.94	27.54	32.17	31.01	29.94	34.78	33.79	31.3	37.39	36.41	34.94	27.27	37.44	40.28	46.75
235	28.25	28.05	27.64	32.15	31.12	30.05	34.80	33.65	31.35	37.44	36.58	34.89	27.17	37.75	40.06	46.59
240	28.25	27.95	27.37	32.2	31.08	30.05	34.78	33.86	31.58	37.36	36.55	34.84	27.44	37.78	40.21	46.78
245	28.08	27.94	27.54	32.35	31.1	30.04	34.92	33.74	31.6	37.49	36.78	35.14	27.17	37.8	40.21	46.92
250	28.2	27.91	27.51	32.25	31.27	30.05	34.99	33.86	31.52	37.72	36.7	34.99	27.35	38.05	40.22	47.13
255	28.23	28.02	27.66	32.37	31.25	30.04	35.01	33.94	31.64	37.64	36.78	35.19	27.23	38.08	40.3	47.03
260	28.35	28.1	27.64	32.4	31.12	30.05	35.03	33.91	31.71	37.66	36.72	35.14	27.46	38.3	40.25	47.03

Table A4.9: Experimental Data for Small Rashig Ring, $d_p = 3.27$ cm.
Run # 9: Re = 1035.5 $Q_w = 79.4\ W/m^2$ $T_{amb} = 26.5\ ^{\circ}C$.
Time in (minutes), Temperature in ($^{\circ}C$) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	26.2	26.25	26.25	26.1	26.2	26.15	26.3	26.3	26.71	26.76	26.56	26.91	26.51	26.76	26.33	26.66
5	26.27	26.27	26.39	26.17	26.08	26.27	26.43	26.39	26.59	26.69	26.79	26.84	26.64	26.84	26.89	27.08
10	26.41	26.33	26.33	26.41	26.33	26.12	26.61	26.46	26.66	26.81	26.66	26.51	26.66	26.76	27.15	27.54
15	26.35	26.35	26.2	26.54	26.39	26.39	26.67	26.49	26.59	26.79	26.79	26.92	26.59	26.92	27.27	27.79
20	26.44	26.44	26.3	26.59	26.39	26.39	26.81	26.69	26.79	27.02	26.84	26.74	26.59	27.08	27.54	28.08
25	26.41	26.61	26.41	26.56	26.51	26.46	26.79	26.81	26.79	27.02	26.92	26.64	26.74	27.02	27.64	28.49
30	26.66	26.54	26.39	26.71	26.66	26.49	26.82	26.91	26.79	26.92	27.15	26.79	26.79	27.25	27.89	28.74
35	26.54	26.49	26.35	26.95	26.74	26.49	27.11	27	26.71	27.27	27.23	27.05	26.86	27.27	28	28.86
40	26.49	26.69	26.44	26.92	26.74	26.69	27.11	26.98	26.95	27.3	27.3	27	26.76	27.37	28.1	29
45	26.61	26.51	26.38	26.95	26.81	26.61	27.19	27.08	27.13	27.42	27.56	27.23	26.79	27.56	28.23	29.27
50	26.69	26.59	26.54	26.98	26.84	26.69	27.29	27.23	27.08	27.59	27.54	27.27	26.79	27.64	28.23	29.45
55	26.74	26.64	26.59	27.08	26.89	26.64	27.40	27.33	27.05	27.71	27.56	27.1	26.81	27.76	28.4	29.56
60	26.69	26.59	26.54	27.17	26.89	26.74	27.48	27.17	27.05	27.79	27.69	27.15	26.76	27.91	28.35	29.66
65	26.69	26.69	26.54	27.08	26.89	26.79	27.40	27.17	27.17	27.71	27.86	27.33	26.86	27.86	28.48	29.79
70	26.69	26.84	26.59	27.23	26.89	26.84	27.55	27.17	27.15	27.86	27.61	27.49	26.91	28	28.45	29.96
75	26.64	26.89	26.64	27.2	26.92	26.79	27.59	27.35	27.27	27.98	27.86	27.46	27.08	28.17	28.61	29.99
80	26.69	26.69	26.59	27.1	27	26.86	27.48	27.3	27.17	27.86	27.76	27.46	26.79	28.27	28.56	30.08
85	26.89	26.79	26.64	27.23	27.08	26.89	27.54	27.23	27.2	27.84	27.95	27.54	27.15	28.25	28.69	30.15
90	26.76	26.91	26.71	27.23	26.86	26.91	27.64	27.37	27.25	28.05	27.86	27.59	27.05	28.25	28.59	30.23
95	26.81	26.86	26.66	27.25	27.15	26.91	27.67	27.51	27.35	28.08	28.08	27.64	27.02	28.38	28.69	30.25
100	26.84	26.79	26.89	27.23	27.23	26.92	27.67	27.51	27.25	28.1	27.91	27.71	27.15	28.3	28.81	30.27
105	26.92	26.92	26.84	27.33	27.17	26.98	27.74	27.42	27.37	28.15	28.05	27.81	27.15	28.3	28.81	30.23
110	26.95	26.95	26.76	27.3	27.2	26.95	27.73	27.4	27.49	28.15	27.94	27.59	27.05	28.45	28.74	30.35
115	26.92	26.89	26.74	27.51	27.13	27.13	27.88	27.46	27.37	28.25	28	27.91	27.13	28.48	28.86	30.38
120	26.91	26.91	26.81	27.49	27.25	27	27.86	27.54	27.44	28.23	28.17	27.89	27.2	28.45	28.79	30.35

Table A4.9: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	27.05	26.91	26.86	27.4	27.2	27.15	27.79	27.64	27.49	28.17	28.13	27.84	27.3	28.54	28.89	30.4
130	27	26.86	26.86	27.46	27.42	27.1	27.86	27.56	27.61	28.25	28.25	28.05	27.25	28.49	28.96	30.48
135	27.1	26.95	26.95	27.4	27.3	27.05	27.90	27.61	27.56	28.4	28.2	28.1	27.3	28.49	29	30.61
140	27.15	27.02	26.98	27.44	27.25	27.2	27.96	27.79	27.54	28.48	28.27	27.89	27.27	28.51	28.84	30.45
145	27.1	26.91	26.91	27.49	27.3	27.1	27.87	27.69	27.59	28.25	28.35	28.1	27.2	28.54	28.91	30.52

Table A4.10: Experimental Data for Small Rashig Ring, $d_p = 3.27$ cm.
Run # 10: Re = 842.8 $Q_w = 79.4$ W/m^2 $T_{amb} = 25.5$ °C.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	25.27	25.23	25.17	25.13	25.35	25.23	25.27	25.39	25.61	25.71	25.76	25.66	25.15	25.71	25.41	25.66
5	25.13	25.08	25.02	25.27	25.36	25.36	25.53	25.36	25.54	25.79	25.79	25.54	25.59	25.79	25.79	26.08
10	25.1	25.2	25.1	25.33	25.25	25.25	25.61	25.41	25.54	25.88	25.88	25.79	25.49	25.84	26.12	26.64
15	25.27	25.23	25.08	25.36	25.36	25.23	25.53	25.41	25.54	25.69	25.79	25.74	25.79	25.92	26.38	26.89
20	25.41	25.33	25.27	25.66	25.36	25.27	25.79	25.61	25.44	25.92	25.92	25.79	25.88	25.92	26.84	27.27
25	25.56	25.46	25.23	25.76	25.56	25.46	25.94	25.81	25.61	26.12	25.95	25.71	26.12	26.02	27	27.61
30	25.61	25.51	25.36	25.86	25.71	25.56	25.96	25.81	25.66	26.05	25.95	25.95	26.05	26.38	27.1	27.81
35	25.66	25.76	25.46	26.05	25.71	25.71	26.11	25.9	25.79	26.17	26.17	25.79	26.08	26.46	27.33	28.13
40	25.66	25.76	25.36	26.05	25.81	25.66	26.15	26.05	25.95	26.25	26.33	26	26	26.46	27.42	28.38
45	25.88	25.84	25.54	26.17	25.79	25.84	26.41	26.17	26.17	26.64	26.33	26.08	26.23	26.59	27.74	28.74
50	25.86	25.81	25.71	26.25	26	25.9	26.41	26.25	26.12	26.56	26.51	26.23	26.17	26.66	27.81	28.89
55	25.69	25.88	25.69	26.27	26.23	25.92	26.52	26.41	26.15	26.76	26.91	26.35	26.1	26.76	28.1	29.05
60	25.84	26	25.69	26.39	26.2	26	26.63	26.39	26.23	26.86	26.86	26.38	26.17	26.86	27.91	29.27
65	25.98	25.88	25.74	26.51	26.12	25.92	26.81	26.51	26.38	27.1	26.91	26.56	26.25	26.95	28.15	29.27
70	26.05	26	25.9	26.51	26.33	26	26.87	26.51	26.3	27.23	27.08	26.69	25.98	27.23	28.17	29.4
75	25.95	26	25.76	26.56	26.33	26	26.91	26.61	26.39	27.25	27.08	26.59	26.15	27.3	28.2	29.61
80	26.1	25.95	25.9	26.56	26.2	26.25	26.92	26.76	26.49	27.27	27.23	26.84	26.25	27.4	28.4	29.76
85	26.15	25.9	26.1	26.59	26.35	26.3	26.97	26.86	26.64	27.35	27.17	26.89	26.25	27.54	28.45	29.76
90	26.08	25.98	25.79	26.74	26.23	26.17	27.06	26.79	26.51	27.37	27.33	26.89	26.27	27.51	28.23	29.91
95	26.12	26.02	25.98	26.56	26.33	26.23	26.98	26.89	26.56	27.4	27.35	26.95	26.2	27.64	28.4	29.99
100	26.23	26.08	25.84	26.61	26.41	26.23	27.04	26.86	26.66	27.46	27.37	27.02	26.17	27.71	28.42	29.94
105	26.1	26.02	25.98	26.54	26.44	26.35	27.09	26.89	26.69	27.64	27.49	26.98	26.25	27.79	28.54	30.15
110	26.1	26.15	26.05	26.59	26.39	26.35	27.09	26.89	26.64	27.59	27.44	27.2	26.35	27.91	28.4	30.17
115	26.08	26.02	26.02	26.71	26.41	26.41	27.15	26.95	26.71	27.59	27.44	26.95	26.05	27.91	28.35	30.13
120	26.12	25.98	25.92	26.69	26.51	26.23	27.18	26.98	26.89	27.66	27.61	27.23	26.27	28.08	28.64	30.48

Table A4.10: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	26.12	26.23	25.92	26.74	26.41	26.38	27.23	27.02	26.69	27.71	27.56	27.27	26.12	27.94	28.48	30.3
130	26.02	26.08	26.08	26.71	26.56	26.23	27.25	27.08	26.64	27.79	27.59	27.33	26.3	28.02	28.4	30.23
135	26.12	26.08	25.88	26.71	26.56	26.17	27.29	26.98	26.69	27.86	27.59	27.2	26.39	27.95	28.54	30.33
140	26.1	26.1	26.1	26.74	26.49	26.35	27.28	27.02	26.81	27.81	27.71	27.13	26.33	28.08	28.56	30.4
145	26.05	26	25.95	26.69	26.49	26.35	27.34	27.05	26.79	27.98	27.64	27.08	26.39	28.17	28.49	30.38
150	26.12	26.12	25.98	26.76	26.51	26.41	27.31	27.02	26.71	27.86	27.76	27.46	26.41	28.15	28.48	30.55
155	26.25	26.02	25.92	26.74	26.49	26.49	27.27	26.92	26.84	27.79	27.69	27.25	26.39	28.2	28.45	30.48
160	26.17	26.23	25.86	26.76	26.66	26.51	27.30	27.25	26.84	27.84	27.79	27.33	26.3	28.23	28.69	30.61
165	26.33	26.2	25.95	26.91	26.61	26.41	27.35	27.1	26.92	27.79	27.74	27.74	26.3	28.27	28.54	30.61

Table A4.11: Experimental Data for Small Rashig Ring, $d_p = 3.27$ cm.
Run # 11: Re = 606.8 $Q_w = 79.4$ W/m^2 $T_{amb} = 25.8$ °C.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	25.79	25.69	25.74	25.79	25.74	25.84	25.79	25.88	26.08	26.23	26.27	26.02	25.39	26.23	26.08	26.23
5	25.64	25.59	25.54	25.69	25.79	25.84	26.00	25.84	26.25	26.3	26.35	26.3	25.51	26.35	26.44	26.69
10	25.74	25.69	25.54	25.79	25.79	25.69	26.00	25.92	26.1	26.2	26.35	26	25.76	26.39	26.76	27.15
15	25.46	25.61	25.51	25.86	25.76	25.71	26.15	25.95	26.15	26.44	26.44	26.3	25.81	26.35	27.15	27.59
20	25.74	25.64	25.59	26.05	25.81	25.81	26.30	26.3	25.95	26.54	26.49	26.1	25.81	26.15	27.4	28.1
25	25.76	25.66	25.66	26.1	25.95	25.86	26.26	26.2	26.23	26.41	26.46	26.17	26.02	26.61	27.71	28.51
30	25.79	25.79	25.59	26.27	25.92	25.92	26.47	26.33	26.17	26.66	26.71	26.27	25.92	26.81	27.86	28.71
35	25.88	25.79	25.74	26.41	26.02	25.88	26.65	26.46	26.23	26.89	26.71	26.46	26.08	26.89	28.13	29.02
40	25.88	25.79	25.79	26.44	26.25	25.92	26.63	26.64	26.39	26.81	26.86	26.44	25.95	26.86	28.45	29.25
45	25.64	25.84	25.59	26.46	26.27	25.98	26.76	26.61	26.39	27.05	27.05	26.49	26.05	27.2	28.4	29.48
50	25.9	25.9	25.71	26.56	26.27	26.1	26.93	26.71	26.39	27.3	27.2	26.49	26	27.25	28.49	29.81
55	25.92	25.92	25.74	26.79	26.41	26.08	27.11	26.84	26.46	27.42	27.27	26.79	26.02	27.33	28.69	29.89
60	26.02	25.69	25.74	26.59	26.49	26.12	27.05	26.89	26.46	27.51	27.33	27.02	26.12	27.56	28.84	30.15
65	25.95	25.9	25.66	26.66	26.38	26.17	27.16	26.86	26.71	27.66	27.4	27.15	26.05	27.66	28.81	30.27
70	26	25.95	25.71	26.76	26.44	26.25	27.21	27	26.56	27.66	27.51	27.23	26.17	27.71	29.08	30.55
75	26.1	26	25.76	26.91	26.56	26.41	27.34	26.95	26.61	27.76	27.71	27.15	26.23	27.71	29.02	30.74
80	25.95	25.95	25.76	26.81	26.49	26.3	27.38	27.1	26.64	27.94	27.71	27.17	26.17	28.02	29.08	30.71
85	26.08	26.02	25.86	26.86	26.56	26.33	27.42	27.05	26.69	27.98	27.71	27.42	26.23	28.08	29.13	30.81
90	26.08	25.98	25.92	26.81	26.56	26.38	27.38	27.2	26.79	27.94	27.84	27.54	26.15	28.15	29.1	30.94
95	25.9	26.05	25.95	26.81	26.44	26.35	27.47	27.2	26.89	28.13	28.13	27.42	26.02	28.08	29.13	30.96
100	26	25.95	26.1	26.92	26.64	26.39	27.45	27.2	26.89	27.98	27.91	27.37	25.98	28.23	29.13	31.01
105	26.05	26	26	26.95	26.59	26.3	27.59	27.35	26.74	28.23	28.02	27.46	26.17	28.38	29.27	31.12
110	26.1	25.9	25.86	27	26.64	26.35	27.64	27.3	26.81	28.27	27.91	27.56	26.17	28.33	29.13	31.15
115	26.15	26.1	25.92	26.89	26.64	26.49	27.57	27.27	26.95	28.25	28.15	27.4	26.33	28.3	29.25	31.35
120	26.12	25.98	26.12	26.92	26.69	26.39	27.69	27.42	26.95	28.45	28.1	27.66	26.27	28.61	29.42	31.35

Table A4.11: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	26.05	26.15	25.95	26.91	26.76	26.41	27.67	27.35	26.92	28.42	28.17	27.61	26.23	28.51	29.38	31.38
130	26.02	26.12	26.02	27.08	26.76	26.46	27.68	27.42	27.13	28.27	28.27	27.69	26.39	28.84	29.35	31.38
135	26.12	26.12	26.02	27.05	26.66	26.51	27.66	27.37	26.92	28.27	28.33	27.84	26.15	28.79	29.3	31.5
140	26.1	26.05	26.05	27.1	26.64	26.54	27.73	27.49	27.05	28.35	28.3	27.76	26.15	28.71	29.51	31.5
145	26.15	26.15	25.95	27.1	26.76	26.51	27.73	27.49	27.15	28.35	28.35	27.95	26.17	29	29.51	31.58
150	26.23	26.12	26.02	27	26.66	26.61	27.70	27.46	27	28.4	28.15	27.81	26.27	29	29.51	31.61
155	26.12	26.08	26.02	27.02	26.79	26.54	27.81	27.46	27.02	28.59	28.38	27.79	26.15	28.89	29.5	31.69
160	26.33	26.23	26.02	27.08	26.89	26.59	27.84	27.46	27.05	28.59	28.45	27.89	26.3	28.96	29.56	31.91
165	26.17	26.23	25.98	27.02	26.91	26.51	27.78	27.51	27.15	28.54	28.4	27.95	26.38	28.96	29.56	31.76
170	26.35	26.3	26.15	27.05	26.84	26.69	27.81	27.59	27.17	28.56	28.42	27.91	26.38	29.08	29.61	31.71
175	26.27	26.23	26.08	27.27	26.76	26.56	27.92	27.46	27.23	28.56	28.42	28.02	26.44	29.08	29.74	31.69
180	26.27	26.46	26.17	27.27	26.84	26.61	28.02	27.46	27.13	28.76	28.56	27.81	26.33	29.08	29.69	31.84
185	26.3	26.39	26.05	27.25	26.95	26.64	27.95	27.59	27.15	28.64	28.64	28.13	26.44	29.1	29.74	32.01
190	26.23	26.33	26.08	27.23	26.89	26.64	27.87	27.61	27.23	28.51	28.33	28.23	26.61	29.17	29.61	31.94
195	26.38	26.38	26.27	27.37	26.91	26.66	28.07	27.51	27.05	28.76	28.49	28.05	26.38	29.2	29.81	31.91
200	26.41	26.38	26.12	27.37	26.98	26.71	28.09	27.66	27.35	28.81	28.66	28.2	26.51	29.3	29.66	31.96

Table A4.12: Experimental Data for Small Rashig Ring, $d_p = 3.27$ cm.
Run # 12: Re = 342.0 $Q_w = 79.4$ W/m^2 $T_{amb} = 25.5$ °C.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	25.41	25.46	25.46	25.61	25.71	25.61	25.71	25.71	25.81	25.9	26	26.1	25.17	26.05	25.81	25.95
5	25.41	25.46	25.41	25.61	25.56	25.66	25.82	25.61	25.92	26.02	26.02	26.17	25.54	26.12	26.39	26.44
10	25.46	25.41	25.46	25.66	25.46	25.56	25.88	25.81	25.84	26.1	26.05	26.1	25.44	26.15	26.64	26.92
15	25.35	25.39	25.25	25.71	25.66	25.49	25.94	25.76	25.92	26.17	26.17	25.98	25.35	26.12	27.13	27.56
20	25.39	25.54	25.44	25.88	25.64	25.59	26.04	25.88	25.81	26.2	26.3	25.86	25.66	26.3	27.59	27.95
25	25.46	25.51	25.46	26	25.81	25.51	26.15	26.15	26.05	26.3	26.41	26.05	25.61	26.3	27.91	28.51
30	25.66	25.46	25.33	26.1	25.86	25.61	26.28	26.1	26	26.46	26.51	26.12	25.46	26.41	28.33	28.81
35	25.59	25.44	25.44	26.17	26.08	25.64	26.37	26.33	26.08	26.56	26.61	26.33	25.61	26.51	28.66	29.33
40	25.64	25.64	25.35	26.39	26.15	25.86	26.65	26.44	26	26.91	26.76	26.38	25.51	26.71	28.86	29.56
45	25.59	25.59	25.44	26.41	26.12	25.84	26.64	26.51	26.15	26.86	26.95	26.39	25.66	26.81	29	29.94
50	25.66	25.61	25.41	26.54	26.35	25.86	26.87	26.64	26.12	27.2	26.95	26.56	25.56	27	29.27	30.25
55	25.79	25.54	25.54	26.61	26.41	26.08	26.97	26.86	26.3	27.33	27.17	26.64	25.69	26.98	29.5	30.61
60	25.64	25.69	25.49	26.76	26.46	26.02	27.13	26.98	26.39	27.49	27.35	26.64	25.76	27.25	29.76	30.94
65	25.71	25.56	25.3	26.84	26.44	26	27.33	27.02	26.27	27.81	27.42	26.91	25.74	27.27	29.84	31.06
70	25.79	25.74	25.54	27.02	26.59	26.12	27.48	27.17	26.44	27.94	27.59	26.95	25.71	27.49	30.04	31.4
75	25.76	25.71	25.56	27.15	26.59	26.1	27.55	27.25	26.61	27.95	27.81	27.1	25.84	27.76	30.13	31.64
80	25.79	25.98	25.56	27.1	26.71	26.23	27.67	27.33	26.59	28.23	27.84	27.17	25.79	27.69	30.25	31.74
85	25.88	25.84	25.54	27.33	26.79	26.27	27.73	27.42	26.69	28.13	28.02	27.27	25.88	27.79	30.52	31.91
90	25.9	25.76	25.61	27.2	26.95	26.35	27.84	27.64	26.89	28.48	28.13	27.42	26.02	28.02	30.61	32.2
95	25.9	25.76	25.71	27.2	26.91	26.2	27.84	27.69	26.86	28.48	28.33	27.51	25.64	28.27	30.5	32.25
100	26.02	25.95	25.56	27.3	26.86	26.41	28.01	27.76	26.98	28.71	28.42	27.56	25.92	28.17	30.55	32.42
105	26.02	25.84	25.59	27.33	26.98	26.51	28.04	27.76	26.92	28.74	28.42	27.79	25.92	28.48	30.86	32.74
110	26	25.9	25.71	27.44	27	26.49	28.20	27.91	27	28.96	28.71	27.61	25.88	28.51	30.86	32.76
115	26.05	25.86	25.66	27.44	26.98	26.49	28.25	27.94	27.15	29.05	28.69	27.89	25.9	28.74	30.89	32.96
120	26.05	25.9	25.56	27.64	27.05	26.49	28.35	27.89	27	29.05	28.86	28.1	25.9	28.76	31.06	33.09

Table A4.12: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	26.02	25.98	25.74	27.56	27.17	26.41	28.37	28.17	27.27	29.17	29.02	28	25.88	28.91	31.1	33.14
130	26.08	26.08	25.79	27.61	27.08	26.61	28.42	28.02	27.23	29.23	28.94	28.08	25.98	29.02	31.12	33.3
135	26.25	26	25.81	27.59	27.2	26.69	28.49	28.15	27.2	29.38	28.96	28.25	26	28.96	31.06	33.55
140	26.05	26.05	25.9	27.69	27.25	26.64	28.57	28.17	27.27	29.45	29.25	28.64	26.05	29.25	31.27	33.47
145	26.27	26.02	25.74	27.61	27.37	26.69	28.56	28.27	27.33	29.51	29.13	28.33	26.02	29.23	31.25	33.69
150	26.17	26.02	25.84	27.71	27.25	26.71	28.70	28.33	27.44	29.69	29.35	28.54	26.1	29.5	31.33	33.53
155	26.15	26.05	25.86	27.79	27.3	26.69	28.78	28.35	27.4	29.76	29.3	28.49	25.95	29.56	31.45	33.65
160	26.2	26	25.81	27.91	27.25	26.76	28.84	28.4	27.49	29.76	29.4	28.86	26.05	29.61	31.35	33.79
165	26.12	26.08	25.79	27.84	27.37	26.79	28.89	28.48	27.51	29.94	29.48	28.76	26.08	29.51	31.3	33.91
170	26.05	26	25.71	27.91	27.54	26.91	28.88	28.45	27.54	29.84	29.4	28.74	25.95	29.79	31.42	34.04
175	26.3	26	25.9	27.94	27.35	26.92	28.93	28.49	27.54	29.91	29.51	28.64	25.95	30.01	31.45	34.06
180	26.15	26.1	25.86	27.79	27.44	26.91	28.89	28.45	27.42	29.99	29.56	28.71	26.02	30.04	31.42	34.19
185	26.35	26.2	25.86	27.84	27.54	26.86	28.97	28.45	27.54	30.1	29.64	28.89	26.1	30.01	31.55	34.16
190	26.41	26.23	25.98	27.81	27.42	26.86	28.93	28.66	27.59	30.05	29.71	29	26.25	30.15	31.55	34.2
195	26.38	26.27	25.98	28.05	27.56	26.98	29.03	28.51	27.71	30.01	29.76	29	26.17	30.23	31.55	34.25
200	26.33	26.27	26.08	28.05	27.42	26.98	29.14	28.76	27.64	30.23	29.86	29.05	26	30.33	31.64	34.35
205	26.38	26.27	25.98	28.05	27.76	26.92	29.15	28.61	27.71	30.25	29.84	28.99	26.02	30.25	31.66	34.33
210	26.25	26.35	26	28.08	27.56	27.08	29.17	28.74	27.74	30.25	30.01	29.1	26.2	30.3	31.79	34.45
215	26.3	26.15	26	28	27.64	27	29.25	28.64	27.79	30.5	30.04	29.23	26.1	30.3	31.58	34.4
220	26.35	26.25	25.95	28.02	27.69	27.02	29.24	28.69	27.79	30.45	29.89	29.17	26.2	30.4	31.74	34.45
225	26.3	26.25	26	28.1	27.54	27	29.23	28.69	27.79	30.35	30.1	29.4	26.2	30.56	31.64	34.63
230	26.39	26.3	26.1	28.08	27.74	27.02	29.27	28.79	27.89	30.45	30.1	29.27	26	30.59	31.89	34.55

Table A5.1: Experimental Data for Large Rashig Ring, $d_p = 3.87$ cm.
Run # 1: Re = 1065.9 $Q_W = 179.2\ W/m^2$ $T_{amb} = 24.5\ ^{o}C$.
Time in (minutes), Temperature in (^{o}C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	23.85	23.76	23.8	23.8	23.76	23.98	24.13	24.23	24.31	24.51	24.41	24.31	23.83	24.51	24.27	24.46
5	23.8	23.76	23.61	23.61	23.66	23.85	23.95	24.15	24.34	24.39	24.49	24.25	24.1	24.34	24.92	25.36
10	24	23.9	23.76	23.95	23.8	23.9	24.25	24.25	24.3	24.54	24.49	24.25	24.25	24.79	25.98	26.38
15	24.27	23.98	23.74	23.92	23.88	24.08	24.31	24.27	24.27	24.9	24.66	24.41	24.31	24.81	26.84	27.13
20	24.2	24.1	23.95	24.2	24.1	24.1	24.54	24.49	24.44	24.98	24.79	24.64	24.39	25.17	27.59	28.05
25	24.34	24.05	23.95	24.25	24.1	24.15	24.74	24.39	24.51	25.2	24.95	24.76	24.17	25.39	28.13	28.84
30	24.56	24.23	24.13	24.51	24.23	24.27	25	24.61	24.76	25.54	25.25	24.85	24.36	25.49	28.71	29.42
35	24.61	24.41	24.13	24.41	24.27	24.27	25.25	24.66	24.74	25.66	25.41	25.36	24.3	25.86	29.05	29.96
40	24.66	24.27	24.08	24.56	24.36	24.56	25.44	25	24.83	25.9	25.56	25.46	24.79	26.15	29.4	30.4
45	24.64	24.34	24.05	24.74	24.44	24.54	25.61	25.08	24.98	26.05	25.71	25.61	24.49	26.35	29.74	30.81
50	24.61	24.36	24.31	24.71	24.56	24.56	25.69	25.35	25.25	26.33	26.02	25.84	24.66	26.61	30.1	31.33
55	24.59	24.3	24.3	24.79	24.64	24.69	25.76	25.33	25.27	26.49	26	26.05	24.44	26.89	30.04	31.61
60	24.9	24.61	24.31	24.95	24.76	24.85	25.92	25.44	25.2	26.71	26.33	26.17	24.61	27.05	30.4	31.94
65	24.9	24.46	24.31	24.85	24.71	24.81	26.08	25.64	25.36	26.84	26.39	26.25	24.69	27.23	30.66	32.11
70	25.02	24.54	24.39	24.87	24.87	24.79	26.1	25.66	25.54	27.08	26.51	26.17	24.79	27.37	30.86	32.4
75	24.98	24.64	24.34	25.17	24.79	24.92	26.1	25.66	25.54	27.05	26.66	26.41	24.66	27.59	30.89	32.84
80	24.92	24.54	24.44	25.02	24.98	25.02	26.25	25.76	25.64	27.3	26.81	26.56	24.81	27.64	31.15	32.91
85	25	24.51	24.41	25.15	24.9	25.05	26.17	25.84	25.81	27.17	26.89	26.59	24.41	27.89	31.25	32.94
90	25.13	24.85	24.51	25.13	24.98	25.02	26.46	25.81	25.79	27.66	27	26.81	24.98	28.15	31.52	33.28
95	25.1	24.66	24.61	25.1	25.05	25.05	26.46	25.92	25.76	27.66	27.17	26.74	24.87	28.1	31.66	33.47
100	25.05	24.81	24.39	25.44	25.05	25.2	26.51	25.92	25.92	27.66	27	26.95	24.87	28.25	31.81	33.71
105	25.13	24.64	24.59	25.17	25.02	25.17	26.54	26	26.02	27.76	27.25	26.91	24.54	28.25	31.96	33.67
110	25.23	24.71	24.61	25.27	25.08	25.23	26.54	26.1	26	27.66	27.37	27.17	24.71	28.48	31.89	33.79
115	25.08	24.79	24.54	25.36	25.13	25.27	26.59	26.25	26	27.86	27.42	27.17	24.74	28.49	31.86	33.81
120	25.27	24.92	24.64	25.41	25.02	25.23	26.79	26.3	25.98	27.98	27.4	27.4	24.64	28.74	31.79	34.11

Table A5.1: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	25.23	24.74	24.59	25.41	25.17	25.23	26.74	26.3	26.15	27.91	27.46	27.27	24.81	28.71	32.04	34.09
130	25.25	24.71	24.71	25.39	25.25	25.3	26.81	26.25	26.12	27.94	27.54	27.25	25.02	28.74	32.15	34.01
135	25.17	24.83	24.64	25.54	25.17	25.25	26.76	26.23	26.2	28.08	27.59	27.27	25.05	28.76	32.09	34.16
140	25.2	24.85	24.71	25.33	25.2	25.3	26.74	26.3	26.1	28.05	27.51	27.46	25.02	28.84	32.06	34.22
145	25.23	24.98	24.79	25.51	25.33	25.36	26.89	26.35	26.3	28.23	27.66	27.56	24.85	28.81	32.04	34.4
150	25.25	24.79	24.64	25.39	25.39	25.49	26.91	26.51	26.38	28.17	27.84	27.64	25.25	28.86	32.3	34.35
155	25.3	24.9	24.76	25.59	25.2	25.39	26.81	26.46	26.51	28.08	27.69	27.35	24.85	28.99	32.2	34.35
160	25.27	24.98	24.64	25.51	25.23	25.41	26.92	26.49	26.39	28.3	27.81	27.46	24.9	29.05	32.17	34.45
165	25.35	25	24.81	25.54	25.35	25.44	26.95	26.51	26.54	28.38	27.81	27.61	25.15	28.96	32.13	34.45
170	25.25	25.08	24.69	25.54	25.17	25.39	26.95	26.51	26.39	28.35	27.81	27.51	25.13	29.1	32.17	34.5
175	25.54	25	24.81	25.49	25.39	25.59	26.95	26.51	26.51	28.2	27.84	27.59	24.87	29.02	32.25	34.63
180	25.39	24.95	25	25.64	25.39	25.54	27	26.66	26.49	28.35	27.81	27.71	25.17	29.13	32.47	34.47
185	25.36	25.02	24.87	25.41	25.46	25.61	27.13	26.59	26.33	28.42	27.79	27.74	25.08	29.27	32.45	34.67
190	25.51	25.13	24.92	25.61	25.51	25.56	26.98	26.64	26.39	28.4	27.95	27.61	25.36	29.25	32.63	34.7
195	25.46	25.13	24.98	25.76	25.56	25.66	27.08	26.64	26.54	28.48	28	27.76	25.39	29.25	32.55	34.76
200	25.49	25.25	25	25.74	25.54	25.59	27.15	26.66	26.66	28.33	27.89	27.94	25.25	29.27	32.5	34.91
205	25.64	25.25	25.1	25.84	25.69	25.54	27.2	26.61	26.66	28.56	28.08	27.79	25.35	29.27	32.71	34.72
210	25.69	25.39	25.15	25.79	25.74	25.69	27.2	26.76	26.71	28.69	28.08	27.69	25.36	29.42	32.58	34.63
215	25.79	25.3	25.2	26.02	25.69	25.69	27.25	26.71	26.66	28.61	28.17	27.84	25.44	29.56	32.6	34.86
220	25.71	25.36	25.13	25.9	25.61	25.76	27.23	26.74	26.64	28.48	28.13	27.98	25.49	29.45	32.6	34.81
225	25.71	25.36	25.27	25.86	25.71	25.86	27.33	26.74	26.81	28.61	28.27	27.98	25.69	29.42	32.86	34.91
230	25.79	25.36	25.27	25.88	25.88	25.84	27.27	26.86	26.89	28.56	28.17	28	25.49	29.59	32.84	35.01
235	25.88	25.36	25.23	26.08	25.84	25.74	27.42	26.91	26.79	28.69	28.2	28.1	25.66	29.74	32.81	35.16
240	25.86	25.46	25.33	25.95	26	26.05	27.46	26.84	27	28.69	28.38	28.17	25.61	29.76	33.01	35.25
245	25.88	25.44	25.2	26.02	25.79	25.92	27.59	27.05	26.89	28.86	28.15	28.35	25.86	29.74	33.04	35.25
250	25.98	25.54	25.39	26.17	25.98	26.17	27.54	27	26.91	28.99	28.45	28.15	25.76	29.84	33.28	35.3
255	25.95	25.56	25.33	26.2	25.95	26.05	27.66	27.13	26.92	29.05	28.48	28.17	25.44	29.91	33.25	35.42
260	25.84	25.59	25.3	26.12	25.92	25.98	27.59	27.15	26.98	28.89	28.45	28.15	25.51	29.79	33.14	35.47

Table A5.1: (Continued)

265	25.88	25.56	25.46	26.12	25.98	26.08	27.71	27	27.08	28.96	28.4	28.25	25.74	29.89	33.14	35.38
270	25.95	25.61	25.27	26.15	26.05	26.05	27.61	27.13	27.1	28.89	28.59	28.27	25.66	29.99	33.11	35.33
275	25.81	25.61	25.36	26.1	26.05	26.1	27.71	27.13	27.1	29	28.56	28.42	25.59	29.86	33.3	35.33
280	26.1	25.51	25.46	26.2	25.86	26.05	27.71	27.17	27.2	28.91	28.51	28.48	25.79	29.96	33.35	35.42
285	26	25.61	25.41	26.15	25.86	26	27.61	27.13	27.02	29.15	28.54	28.45	25.66	30.08	33.28	35.58
290	25.95	25.61	25.51	26.15	26	26.1	27.76	27.17	27.05	29	28.76	28.38	25.88	30.01	33.35	35.47
295	26.05	25.54	25.44	26.15	25.95	26.05	27.71	27.33	27.3	29.05	28.61	28.38	25.64	29.96	33.06	35.42
300	25.88	25.79	25.3	26.17	26.02	26.17	27.79	27.35	27.13	29.13	28.64	28.35	25.33	30.08	33.11	35.5
305	25.98	25.49	25.44	26.17	26.02	26.17	27.79	27.35	27.08	29.25	28.69	28.45	25.25	30.08	33.09	35.45
310	25.88	25.44	25.35	25.98	25.88	26.17	27.64	27.35	27.27	29.2	28.66	28.61	25.49	30.01	32.94	35.42
315	25.9	25.46	25.17	26.05	25.95	26.2	27.51	27.46	27.08	29.17	28.79	28.4	25.33	30.08	33.01	35.45
320	25.79	25.54	25.25	25.92	25.88	26.02	27.54	27.2	27.17	29.02	28.64	28.2	25.3	30.17	32.99	35.45
325	25.9	25.51	25.27	26.05	25.9	26.05	27.61	27.27	27.15	29.13	28.69	28.49	25.56	30.13	33.08	35.5
330	25.9	25.46	25.27	25.95	26.05	26	27.61	27.27	27.23	29.05	28.76	28.48	25.3	29.96	32.94	35.47
335	25.84	25.44	25.35	25.92	25.98	26.02	27.64	27.3	27.23	29.05	28.49	28.69	25.46	30.08	32.94	35.42
340	25.71	25.41	25.05	25.95	25.76	25.86	27.44	27.13	27.15	29.05	28.61	28.51	25.2	29.91	32.84	35.55
345	25.81	25.33	25.23	26	25.81	26	27.66	27.42	27.2	29.17	28.64	28.54	25.46	30.08	33.14	35.5
350	25.66	25.33	25.13	25.9	25.86	26.05	27.61	27.17	27.02	29	28.56	28.23	25.25	29.91	32.94	35.42
355	25.54	25.15	25.2	25.79	25.79	25.84	27.49	27.2	27.13	29.05	28.56	28.56	25.35	30.01	33.04	35.42

Table A5.2: Experimental Data for Large Rashig Ring, $d_p = 3.87$ cm.
Run # 2: Re = 1065.9 $Q_w = 79.4$ W/m^2 $T_{amb} = 24.5$ °C.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	24.74	24.74	24.51	24.46	24.46	24.69	24.56	24.61	24.85	24.85	24.85	24.81	24.81	25.05	24.9	25
5	24.64	24.74	24.74	24.54	24.54	24.64	24.64	24.74	24.87	24.87	24.79	24.83	24.83	24.83	25.27	25.36
10	24.95	24.74	24.64	24.79	24.74	24.59	24.95	24.79	24.76	25.05	25	24.76	25.15	25	25.79	25.84
15	24.95	24.9	24.81	24.81	24.61	24.81	24.81	24.81	24.83	25.13	25.08	24.98	24.92	25.08	26.23	26.46
20	24.95	25.05	24.95	24.9	24.76	24.85	25	25	25.02	25.41	25.02	25.17	25.36	25.23	26.49	26.61
25	25.02	24.98	24.87	24.87	24.87	24.83	25.13	25.02	24.92	25.46	25.23	25.13	25.23	25.41	26.79	26.92
30	25.2	24.9	24.9	25.1	24.76	24.9	25.2	25.05	25.23	25.56	25.33	25.13	25.23	25.61	27.1	27.35
35	25.13	25.13	25.02	25.02	24.83	24.92	25.27	25.13	25.27	25.66	25.56	25.36	25.17	25.71	27.2	27.59
40	25.3	25.15	25.05	25.15	24.95	25.1	25.39	25.15	25.33	25.71	25.56	25.56	25.27	25.9	27.33	27.86
45	25.33	25.08	25.02	25.27	25.02	25.13	25.41	25.41	25.3	25.84	25.64	25.44	25.39	25.79	27.4	27.95
50	25.35	25.2	25	25.2	25.1	25.2	25.69	25.25	25.41	25.9	25.86	25.66	25.41	26.1	27.76	28.1
55	25.33	25.13	24.98	25.17	25.13	25.17	25.66	25.46	25.41	26	25.9	25.81	25.46	26.05	27.76	28.48
60	25.46	25.36	25.36	25.23	25.23	25.33	25.71	25.51	25.69	26.27	26.02	25.92	25.49	26.12	27.94	28.59
65	25.64	25.44	25.2	25.3	25.3	25.39	25.88	25.69	25.59	26.27	25.88	25.92	25.74	26.27	28.1	28.59
70	25.51	25.46	25.08	25.41	25.27	25.36	25.81	25.56	25.64	26.46	26.23	26.02	25.54	26.41	28.15	28.74
75	25.54	25.44	25.25	25.44	25.39	25.39	26.02	25.74	25.66	26.44	26.25	26.05	25.56	26.54	28.2	28.96
80	25.56	25.36	25.23	25.46	25.17	25.46	25.95	25.86	25.76	26.44	26.15	26.15	25.66	26.59	28.2	28.96
85	25.51	25.51	25.23	25.51	25.46	25.41	26	25.86	25.84	26.44	26.23	25.98	25.79	26.74	28.33	29.15
90	25.61	25.46	25.36	25.51	25.46	25.51	26.2	25.86	25.74	26.59	26.44	26.25	25.64	26.69	28.51	29.1
95	25.81	25.46	25.36	25.66	25.51	25.51	26.17	25.95	25.92	26.64	26.44	26.23	25.64	26.98	28.48	29.38
100	25.71	25.56	25.41	25.61	25.51	25.56	26.1	25.95	26.02	26.71	26.61	26.41	25.88	26.91	28.56	29.23
105	25.64	25.44	25.25	25.64	25.54	25.59	26.33	25.88	26.02	26.76	26.51	26.41	25.64	27.1	28.56	29.56
110	25.71	25.56	25.46	25.56	25.66	25.61	26.3	26	26	26.79	26.59	26.59	25.64	27.02	28.56	29.64
115	25.79	25.54	25.39	25.64	25.54	25.64	26.23	26.08	26.12	26.91	26.51	26.41	25.56	27.1	28.59	29.51
120	25.71	25.56	25.46	25.66	25.56	25.71	26.35	25.95	26.02	26.95	26.66	26.66	25.88	27.1	28.66	29.51

Table A5.2: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	25.86	25.66	25.56	25.66	25.56	25.71	26.3	26.1	26.1	26.92	26.79	26.39	25.88	27.17	28.81	29.69
130	25.84	25.69	25.49	25.84	25.69	25.74	26.33	26.17	26.12	27.02	26.49	26.44	25.84	27.23	28.81	29.81
135	25.88	25.59	25.44	25.79	25.64	25.84	26.51	26.17	26.39	27.02	26.89	26.59	25.9	27.33	28.69	29.79
140	25.9	25.9	25.51	25.86	25.66	25.76	26.39	26.25	26.33	27.02	26.89	26.51	25.84	27.27	28.91	29.69
145	25.98	25.74	25.64	25.88	25.74	25.84	26.46	26.12	26.33	27.1	26.71	26.71	25.88	27.25	28.91	29.96
150	25.95	25.66	25.51	25.81	25.76	25.81	26.64	26.25	26.12	27.2	26.86	26.91	25.92	27.4	29	29.76
155	25.98	25.74	25.59	25.84	25.88	25.79	26.61	26.27	26.35	27.2	26.81	26.79	25.76	27.4	28.99	29.81
160	25.98	25.79	25.59	25.92	25.88	25.92	26.56	26.41	26.35	27.23	27.02	26.89	25.76	27.42	28.99	29.99
165	25.9	25.76	25.61	25.95	25.81	25.86	26.59	26.39	26.56	27.2	26.86	26.91	25.88	27.44	28.96	29.86
170	25.92	25.79	25.74	25.88	25.88	26.02	26.51	26.38	26.3	27.17	26.98	26.89	25.95	27.61	28.99	29.99
175	25.95	25.76	25.56	26	25.81	25.86	26.59	26.39	26.46	27.25	27	27	25.98	27.59	29	30.05
180	26.15	25.66	25.76	25.9	25.9	25.95	26.59	26.39	26.51	27.27	27.02	26.89	25.92	27.61	29	30.05
185	26.12	25.92	25.64	25.98	25.79	25.88	26.66	26.33	26.39	27.37	27.13	27.02	25.84	27.71	29	30.13
190	26.02	25.88	25.64	26.02	25.92	25.79	26.66	26.51	26.46	27.25	27.05	26.95	25.92	27.69	29	30.25
195	26.08	25.84	25.64	26.02	25.92	25.84	26.66	26.51	26.51	27.3	27.05	27	25.95	27.69	29.08	30.1
200	26	25.86	25.71	25.95	25.9	25.86	26.59	26.49	26.41	27.54	27	27	25.92	27.54	28.91	30.15
205	25.92	25.79	25.59	25.88	25.92	25.88	26.76	26.56	26.56	27.4	27.2	27.1	25.95	27.64	29.08	30.17
210	26.08	25.84	25.64	25.92	25.84	25.92	26.61	26.46	26.51	27.27	27.08	26.92	25.98	27.71	29.05	30.04
215	26.02	25.84	25.64	25.92	25.88	25.88	26.71	26.61	26.46	27.44	27.1	27.15	26.02	27.69	29.1	30.15
220	26.05	25.86	25.66	25.95	25.76	26.05	26.64	26.59	26.51	27.35	27.2	27.1	25.95	27.79	28.86	30.01
225	26.1	25.81	25.61	25.9	26	25.86	26.64	26.54	26.51	27.46	27.13	26.98	26.12	27.76	29.1	30.3
230	26.12	25.86	25.61	25.92	25.9	25.92	26.66	26.46	26.61	27.64	27.25	26.95	26.02	27.89	29.15	30.2
235	25.95	25.9	25.66	25.95	25.76	25.86	26.74	26.59	26.56	27.44	27.25	27.05	25.95	27.64	29.08	30.2
240	26.02	25.84	25.84	25.88	25.98	26.02	26.71	26.56	26.59	27.42	27.23	27.08	25.92	27.76	29.17	30.33
245	26.12	25.84	25.69	26.08	25.88	26.08	26.71	26.56	26.61	27.35	27.15	26.91	26.05	27.79	29.23	30.3
250	26.12	25.98	25.74	26.08	25.79	26.08	26.76	26.66	26.66	27.33	27.17	27.13	25.98	27.81	29.2	30.33
255	26.1	25.84	25.69	25.95	25.95	26	26.79	26.64	26.69	27.46	27.17	27.08	25.86	27.71	29.08	30.23
260	26.17	25.98	25.79	26.12	25.88	26.12	26.66	26.46	26.56	27.35	27.25	27.15	26	27.84	29.17	30.4

Table A5.2: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
265	26.15	25.95	25.81	26.15	26	26	26.79	26.54	26.64	27.49	27.2	26.92	25.95	27.84	29.27	30.3
270	26.12	25.98	25.79	26.02	25.98	25.92	26.56	26.56	26.56	27.44	27.35	27.1	26.02	27.84	29	30.15
275	26.12	25.88	25.98	26.02	26.08	26.23	26.81	26.66	26.49	27.42	27.37	27.08	26	27.91	29.17	30.25
280	26.02	25.88	25.74	26.17	26.08	26.02	26.81	26.46	26.61	27.4	27.25	27.1	26.02	28	29.3	30.35
285	26.25	25.9	25.86	25.95	26	26.1	26.79	26.64	26.69	27.59	27.4	26.95	26.05	28.08	29.02	30.4
290	26.12	25.98	25.81	26.17	26.02	26.08	26.86	26.56	26.69	27.71	27.27	27.27	26.17	27.86	29.17	30.52
295	26.25	26.1	25.86	26.2	26	26.1	26.84	26.59	26.66	27.59	27.3	27.2	26.3	27.89	29.2	30.35
300	26.15	26	25.86	26.05	26	26.1	26.79	26.49	26.69	27.56	27.37	27.17	26.15	27.95	29.33	30.33
305	26.2	26.05	25.76	26.2	26.15	26.15	26.79	26.69	26.81	27.69	27.4	27.3	26.12	28.02	29.35	30.45
310	26.12	26.12	25.92	26.23	26.08	26.17	26.95	26.71	26.64	27.56	27.42	27.27	26.39	28.05	29.33	30.38
315	26.25	26.1	25.81	26.15	26.15	26.3	26.74	26.74	26.76	27.66	27.51	27.33	26.27	28.05	29.25	30.42
320	26.15	26	25.86	26.25	26.15	26.2	26.86	26.61	26.74	27.51	27.37	27.08	26.23	27.95	29.23	30.42
325	26.35	26.05	26	26.35	26.3	26.2	26.98	26.74	26.84	27.44	27.35	27.4	26.2	28.02	29.38	30.45
330	26.35	26.15	26.15	26.25	26.2	26.35	26.98	26.84	26.79	27.61	27.42	27.37	26.33	28	29.54	30.42
335	26.33	26.1	26	26.27	26.23	26.27	26.86	26.76	26.74	27.66	27.46	27.37	26.39	28.05	29.56	30.56
340	26.39	26.15	25.95	26.2	26.15	26.3	26.98	26.79	26.89	27.61	27.37	27.42	26.17	27.95	29.48	30.48
345	26.39	26.15	26	26.35	25.95	26.2	26.92	26.64	26.86	27.71	27.46	27.42	26.17	28	29.45	30.52
350	26.25	26.15	26.1	26.25	26.25	26.39	26.92	26.89	26.89	27.76	27.51	27.27	26.12	28	29.38	30.52
355	26.25	26.05	25.86	26.15	26.15	26.3	26.92	26.92	26.91	27.59	27.44	27.44	26.3	27.98	29.25	30.3
360	26.27	26.08	26.02	26.08	26.17	26.33	26.91	26.76	26.92	27.76	27.42	27.46	26.25	28.05	29.38	30.48
365	26.33	26.12	25.92	26.17	26.02	26.33	26.91	26.71	26.98	27.66	27.51	27.17	26.25	28.15	29.38	30.71
370	26.35	26.05	25.95	26.2	26.15	26.35	26.92	26.84	26.71	27.76	27.51	27.27	26.12	28.25	29.35	30.48
375	26.33	26.02	25.88	26.17	26.17	26.27	26.95	26.81	26.79	27.81	27.46	27.46	25.95	28.1	29.56	30.48
380	26.27	26.02	25.79	26.27	26.17	26.23	26.91	26.91	26.92	27.69	27.54	27.44	26.3	28.08	29.38	30.66
385	26.25	26.1	26	26.15	26.2	26.15	26.92	26.89	26.84	27.86	27.51	27.42	26.2	28.2	29.42	30.61
390	26.41	26.08	25.98	26.41	26.17	26.38	26.95	26.91	26.89	27.86	27.46	27.37	26.12	28.1	29.23	30.52

Table A5.3: Experimental Data for Large Rashig Ring, $d_p = 3.87$ cm.
Run # 2: Re = 880.6 $Q_w = 79.4\ W/m^2$ $T_{amb} = 24.5\ ^oC$.
Time in (minutes), Temperature in (^oC) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	$T_w 1$	$T_w 2$
0	24.56	24.46	24.41	24.36	24.36	24.41	24.41	24.46	24.59	24.79	24.74	24.49	24.79	24.83	24.79	24.74
5	24.81	24.85	24.71	24.51	24.56	24.56	24.51	24.41	24.76	24.76	24.81	24.76	25	24.9	25.39	25.35
10	24.74	24.74	24.44	24.59	24.34	24.44	24.54	24.59	24.83	24.83	24.92	24.87	25.27	25.02	25.81	25.71
15	25	24.95	24.76	24.81	24.71	24.66	24.71	24.85	24.81	25.1	25.1	24.61	25.36	25.1	26.3	26.3
20	24.9	24.85	24.76	24.85	24.66	24.81	24.95	24.81	25.1	25.1	25.1	25	25.3	25.25	26.74	26.54
25	25.05	25	24.95	24.95	24.9	24.85	25.1	24.95	25	25.39	25.25	25.2	25.39	25.44	27.08	27.17
30	25.2	25.2	24.85	25	24.95	25	25.3	25	25.15	25.39	25.35	25.2	25.39	25.49	27.27	27.4
35	25.17	25.13	24.83	25.08	25.02	25.02	25.41	25.08	25.2	25.64	25.49	25.2	25.35	25.64	27.61	27.66
40	25.25	25	25	25.15	24.95	25	25.59	25.2	25.27	25.81	25.56	25.46	25.36	25.81	27.79	27.98
45	25.35	25.1	25.1	25.25	25.05	25.1	25.59	25.35	25.35	26	25.76	25.66	25.35	26.05	27.89	28.38
50	25.33	25.08	24.92	25.27	25.17	25.23	25.61	25.33	25.49	26.17	25.98	25.69	25.44	26.02	28.15	28.33
55	25.41	25.27	25.23	25.27	25.33	25.36	25.71	25.51	25.41	26.25	25.9	25.9	25.46	26.25	28.3	28.74
60	25.36	25.27	25.23	25.27	25.23	25.33	25.71	25.46	25.54	26.38	26.08	25.88	25.44	26.49	28.48	28.76
65	25.46	25.27	25.17	25.46	25.27	25.33	25.9	25.56	25.71	26.51	26.15	25.95	25.51	26.51	28.64	29.05
70	25.46	25.17	25.08	25.51	25.23	25.33	25.9	25.71	25.71	26.39	26.2	25.9	25.61	26.59	28.74	29.02
75	25.46	25.27	25.33	25.51	25.36	25.36	26.05	25.81	25.81	26.61	26.41	26.25	25.46	26.76	28.89	29.25
80	25.51	25.41	25.13	25.61	25.36	25.41	26.1	25.76	25.92	26.66	26.23	26.27	25.49	26.71	28.66	29.48
85	25.46	25.33	25.23	25.56	25.51	25.46	26.15	25.9	25.86	26.69	26.49	26.2	25.36	26.89	28.91	29.48
90	25.49	25.39	25.25	25.54	25.39	25.49	26.23	25.79	25.88	26.76	26.56	26.23	25.39	27	28.96	29.81
95	25.66	25.46	25.27	25.56	25.56	25.56	26.25	25.9	25.98	26.95	26.66	26.41	25.35	27.05	29.3	29.86
100	25.69	25.44	25.39	25.54	25.44	25.59	26.38	25.92	26.02	27.13	26.74	26.49	25.44	27.13	29.05	29.76
105	25.51	25.35	25.3	25.56	25.49	25.61	26.35	25.95	26	26.98	26.69	26.64	25.61	27.17	29.08	30.08
110	25.54	25.39	25.35	25.69	25.54	25.59	26.2	26	26.12	26.91	26.71	26.66	25.35	27.25	29.25	29.96
115	25.56	25.33	25.33	25.61	25.51	25.66	26.39	26.1	26.25	27.08	26.84	26.59	25.46	27.23	29.38	30.17
120	25.69	25.44	25.25	25.69	25.54	25.54	26.41	26.12	26.1	27.08	26.89	26.69	25.36	27.35	29.27	30.08

Table A5.3: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	25.66	25.46	25.15	25.51	25.51	25.51	26.44	26.05	26.27	27.08	26.89	26.84	25.69	27.33	29.35	30.15
130	25.56	25.46	25.27	25.61	25.66	25.61	26.3	26.05	26.2	27.2	26.81	26.76	25.46	27.49	29.45	30.25
135	25.61	25.33	25.17	25.61	25.51	25.71	26.44	26.1	26.12	27.2	26.95	26.71	25.54	27.59	29.45	30.35
140	25.44	25.35	25.25	25.54	25.54	25.69	26.38	26.17	26.17	27.37	27	26.81	25.59	27.51	29.35	30.25
145	25.64	25.35	25.2	25.54	25.59	25.69	26.56	26.23	26.17	27.25	26.95	26.95	25.54	27.59	29.4	30.2
150	25.69	25.49	25.3	25.69	25.69	25.64	26.41	26.27	26.35	27.27	26.98	27.17	25.66	27.61	29.42	30.27
155	25.66	25.51	25.27	25.56	25.61	25.76	26.35	26.3	26.3	27.33	27.13	26.79	25.56	27.61	29.42	30.48
160	25.66	25.41	25.36	25.61	25.61	25.66	26.49	26.35	26.3	27.27	27.13	26.98	25.56	27.61	29.38	30.33
165	25.69	25.35	25.3	25.74	25.64	25.64	26.51	26.17	26.35	27.4	27	26.69	25.51	27.69	29.48	30.55
170	25.54	25.46	25.27	25.69	25.69	25.74	26.46	26.27	26.41	27.46	27.13	26.98	25.59	27.66	29.5	30.38
175	25.69	25.49	25.35	25.69	25.54	25.79	26.51	26.33	26.23	27.4	27.1	27.05	25.59	27.84	29.5	30.3
180	25.76	25.41	25.23	25.66	25.66	25.66	26.39	26.2	26.41	27.4	27.15	27.05	25.59	27.89	29.38	30.55
185	25.59	25.44	25.25	25.64	25.54	25.84	26.46	26.41	26.2	27.42	27.17	27.08	25.41	27.81	29.56	30.52
190	25.64	25.49	25.39	25.69	25.69	25.79	26.61	26.38	26.38	27.35	27.15	27	25.49	27.84	29.59	30.59
195	25.69	25.49	25.15	25.79	25.74	25.84	26.56	26.27	26.41	27.49	27.1	27	25.49	27.86	29.5	30.66
200	25.74	25.44	25.25	25.74	25.49	25.64	26.61	26.33	26.3	27.46	27.13	27.17	25.51	27.94	29.61	30.69
205	25.66	25.41	25.23	25.76	25.56	25.81	26.64	26.39	26.51	27.49	27.2	27.05	25.59	27.89	29.59	30.59
210	25.54	25.49	25.35	25.74	25.59	25.74	26.61	26.27	26.39	27.44	27.15	26.86	25.59	27.89	29.51	30.69
215	25.69	25.49	25.44	25.79	25.74	25.79	26.61	26.46	26.49	27.56	27.23	27.13	25.61	27.71	29.61	30.66
220	25.66	25.36	25.36	25.76	25.61	25.71	26.59	26.3	26.44	27.61	27.17	27.02	25.76	27.86	29.56	30.81
225	25.79	25.54	25.44	25.88	25.69	25.98	26.64	26.44	26.56	27.4	27.3	27.15	25.59	27.98	29.59	30.69
230	25.76	25.61	25.33	25.81	25.71	25.81	26.44	26.35	26.39	27.46	27.23	27.13	25.66	27.98	29.61	30.69
235	25.79	25.49	25.39	25.79	25.69	25.92	26.61	26.27	26.49	27.61	27.17	27.08	25.41	28.05	29.54	30.66
240	25.54	25.35	25.39	25.74	25.84	25.92	26.66	26.33	26.56	27.54	27.35	27.05	25.79	28.08	29.69	30.96
245	25.76	25.46	25.51	25.71	25.71	25.71	26.64	26.3	26.51	27.56	27.42	27.2	25.74	27.91	29.64	30.66
250	25.69	25.49	25.3	25.88	25.79	25.74	26.56	26.46	26.39	27.42	27.33	26.98	25.51	28	29.76	30.71
255	25.81	25.66	25.46	25.81	25.76	25.81	26.64	26.35	26.41	27.54	27.35	27.05	25.54	28.02	29.74	30.89
260	25.69	25.54	25.35	25.74	25.79	25.88	26.61	26.41	26.56	27.69	27.44	27.2	25.74	27.98	29.69	30.74

Table A5.3: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
265	25.92	25.44	25.44	25.88	25.64	25.84	26.61	26.46	26.51	27.66	27.46	27.08	25.84	28.05	29.69	30.81
270	25.81	25.66	25.46	25.81	25.66	25.86	26.89	26.44	26.54	27.64	27.35	27.08	25.61	27.98	29.61	30.79
275	25.81	25.61	25.41	25.9	25.71	25.95	26.84	26.54	26.46	27.59	27.4	27.05	25.59	28.1	29.69	30.76
280	25.69	25.59	25.49	25.92	25.59	25.79	26.71	26.46	26.66	27.49	27.4	27.1	25.74	28.02	29.79	30.84
285	25.81	25.61	25.46	25.95	25.81	25.95	26.81	26.46	26.59	27.56	27.42	27.17	25.71	28.13	29.71	30.89
290	25.81	25.69	25.64	25.86	25.79	25.9	26.74	26.49	26.51	27.69	27.44	27.2	25.69	28.3	29.84	31.1
295	25.88	25.54	25.49	25.98	25.88	25.98	26.76	26.61	26.49	27.74	27.33	27.13	25.81	28.17	29.76	30.99
300	25.74	25.64	25.49	25.84	25.92	25.98	26.76	26.56	26.41	27.64	27.44	27.4	25.74	28.08	29.84	30.89
305	25.79	25.64	25.54	25.84	25.74	25.92	26.81	26.51	26.49	27.61	27.46	27.37	25.76	28.05	29.76	31.01
310	25.84	25.49	25.39	25.88	25.84	25.88	26.95	26.61	26.61	27.64	27.4	27.3	25.74	28.08	29.74	31.04
315	25.79	25.49	25.44	25.92	25.84	25.98	26.76	26.66	26.44	27.89	27.37	27.46	25.71	28.27	29.86	31.04
320	25.9	25.71	25.46	26.05	25.9	25.95	26.79	26.44	26.76	27.74	27.35	27.25	25.54	28.13	29.84	31.04
325	25.95	25.66	25.41	25.9	25.81	25.95	26.84	26.54	26.64	27.76	27.51	27.33	25.81	28.3	29.81	31.01
330	25.92	25.64	25.54	26.02	25.84	26.12	26.81	26.56	26.54	27.69	27.59	27.37	25.71	28.13	29.86	30.86
335	25.92	25.69	25.49	25.92	25.84	25.98	26.92	26.64	26.61	27.74	27.44	27.3	25.84	28.25	29.94	31.2
340	25.86	25.66	25.46	25.9	25.81	26	26.79	26.44	26.64	27.81	27.46	27.27	25.81	28.17	29.81	31.23
345	25.92	25.64	25.49	25.92	25.84	25.98	26.86	26.56	26.76	27.74	27.54	27.35	25.74	28.27	29.84	31.04
350	26.02	25.74	25.64	26.02	25.92	26.08	26.91	26.76	26.71	27.76	27.51	27.4	25.76	28.25	29.89	31.1
355	25.86	25.76	25.61	26	25.95	25.95	26.98	26.64	26.76	27.89	27.59	27.25	25.74	28.27	29.84	31.2
360	25.86	25.56	25.61	26.15	25.76	26	26.92	26.69	26.64	27.69	27.51	27.37	25.69	28.23	29.81	31.12

Table A5.4: Experimental Data for Large Rashig Ring, $d_p = 3.87$ cm.
Run # 4: Re = 880.6 $Q_w = 179.2$ W/m^2 $T_{amb} = 24.5$ °C.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	25.05	25	24.83	24.74	24.83	24.95	24.95	25.1	25.25	25.44	25.49	25.44	25.3	25.39	25.1	25.2
5	24.85	24.95	24.76	24.85	24.76	24.76	24.9	24.9	25.35	25.44	25.35	25.3	25.39	25.35	26.08	26.17
10	25.13	25.17	25.02	25.17	25.02	25.02	25.23	25.08	25.35	25.54	25.39	25.39	25.49	25.59	27.3	27.59
15	25.33	25.17	24.95	25	24.95	25	25.46	25.13	25.39	25.66	25.49	25.35	25.61	25.81	28.2	28.25
20	25.41	25.36	25.13	25.51	25.17	25.33	25.71	25.27	25.56	26.05	25.9	25.51	25.71	26.15	29.33	29.38
25	25.59	25.3	25.2	25.59	25.39	25.44	26.02	25.59	25.49	26.44	25.98	25.84	25.74	26.39	29.96	30.05
30	25.86	25.51	25.41	25.86	25.71	25.56	26.3	25.76	25.79	26.61	26.23	26.17	25.84	26.71	30.66	30.86
35	25.88	25.49	25.3	25.95	25.74	25.74	26.59	25.95	25.92	26.92	26.54	26.46	25.88	26.98	31.23	31.6
40	26	25.71	25.61	26.05	25.81	25.71	26.79	26.05	26.12	27.17	26.95	26.56	25.79	27.27	31.58	32.04
45	26.02	25.64	25.64	26.12	25.92	25.92	26.92	26.41	26.1	27.54	26.95	26.95	26	27.59	32.15	32.64
50	26.12	25.79	25.59	26.23	26.12	26.02	27.15	26.51	26.3	27.79	27.35	27.1	25.71	27.94	32.47	33.25
55	26.2	25.71	25.66	26.41	26.2	26.05	27.4	26.66	26.54	28.02	27.4	27.35	26.05	28.35	32.89	33.67
60	26.05	25.86	25.61	26.39	26.15	26.3	27.44	26.84	26.81	28.2	27.69	27.64	25.98	28.45	33.17	34.09
65	26.15	25.9	25.61	26.54	26.15	26.3	27.74	26.84	26.61	28.54	27.86	27.76	25.79	28.76	33.25	34.45
70	26.2	25.86	25.56	26.54	26.15	26.3	27.79	26.92	26.76	28.59	28.05	27.79	25.74	28.89	33.5	34.7
75	26.25	25.71	25.71	26.49	26.3	26.39	27.89	27.08	27.02	28.79	28.33	28.17	26.05	29.17	33.67	34.84
80	26.3	26.05	25.71	26.54	26.25	26.44	27.86	27.27	27.02	29.02	28.48	28.02	26.05	29.23	34.04	35.19
85	26.33	25.98	25.79	26.66	26.46	26.41	27.98	27.2	27.13	29.15	28.49	28.25	25.9	29.45	34.16	35.7
90	26.25	25.95	25.74	26.59	26.44	26.59	28.27	27.35	27.3	29.3	28.59	28.35	26.12	29.79	34.58	35.94
95	26.3	25.95	25.86	26.74	26.44	26.74	28.23	27.42	27.25	29.48	28.71	28.48	26.02	29.76	34.5	35.96
100	26.39	26	25.9	26.98	26.69	26.59	28.25	27.66	27.49	29.56	28.91	28.66	26	30.27	34.74	36.21
105	26.49	26	26	26.89	26.69	26.74	28.33	27.66	27.44	29.56	28.99	28.66	26.12	30.08	34.65	36.47
110	26.46	26.23	25.84	26.91	26.51	26.76	28.38	27.74	27.51	29.66	29.2	28.96	25.9	30.42	34.63	36.45
115	26.49	26.1	25.86	26.84	26.74	26.69	28.35	27.71	27.56	29.71	29.2	29.15	26	30.48	34.76	36.67
120	26.54	26.2	25.74	26.79	26.59	26.64	28.48	27.89	27.69	29.89	29.23	28.89	26.12	30.61	34.79	36.75

Table A5.4: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	26.56	26.12	25.92	26.91	26.61	26.71	28.56	27.94	27.79	30.08	29.33	29.08	25.98	30.48	34.89	36.8
130	26.61	26.17	26	26.91	26.71	26.95	28.54	27.91	27.86	30.1	29.59	29.2	26.2	30.64	34.96	36.88
135	26.51	26.23	26.02	27.05	26.86	26.71	28.59	27.89	27.81	30.15	29.4	29.35	26.15	30.79	34.91	36.97
140	26.38	26.17	25.88	26.95	26.81	26.91	28.59	27.94	27.86	30.08	29.64	29.35	26.3	30.94	35.11	37.21
145	26.69	26.15	26.05	26.98	26.64	26.89	28.54	28	27.95	30.17	29.69	29.17	26.1	30.94	35.3	37.09
150	26.66	26.17	26.02	26.95	26.81	27	28.76	28.08	28	30.33	29.59	29.38	26.49	31.04	35.35	37.26
155	26.71	26.33	25.98	27.1	26.81	26.81	28.94	28.08	27.91	30.38	29.69	29.42	26.25	31.08	35.35	37.51
160	26.64	26.2	26.15	27.08	26.79	27.08	28.74	28.2	28.15	30.38	29.84	29.66	26.44	31.23	35.6	37.69
165	26.64	26.25	26.1	27.13	26.89	26.98	28.89	28.25	28.05	30.45	29.79	29.64	26.49	31.3	35.63	37.66
170	26.64	26.3	26.05	27.23	26.98	27.08	28.94	28.3	28.02	30.48	29.86	29.48	26.44	31.42	35.65	37.66
175	26.81	26.38	26.27	27.15	27	27	28.96	28.33	28.08	30.55	29.96	29.61	26.17	31.48	35.47	37.66
180	26.81	26.35	26.15	27.15	27.1	27	28.99	28.3	28.17	30.56	29.96	29.86	26.17	31.52	35.53	37.7
185	26.79	26.25	26.1	27.08	26.92	27.08	28.99	28.25	28.2	30.59	29.89	29.79	26.44	31.45	35.67	37.69
190	26.74	26.49	26.2	27.17	27.13	27.13	28.99	28.2	28.2	30.69	30.08	29.84	26.2	31.74	35.55	37.72
195	26.79	26.35	26.1	27.2	27	27.15	29.08	28.25	28.17	30.61	30.05	29.96	26.51	31.61	35.47	37.69
200	26.91	26.41	26.27	27.2	26.95	27.2	28.91	28.38	28.23	30.66	30.08	30.08	26.35	31.61	35.47	37.8
205	26.79	26.39	26.25	27.27	27.02	27.08	29.13	28.3	28.35	30.55	30.15	30.04	26.49	31.69	35.72	38.05
210	26.84	26.41	26.17	27.23	27.08	27.23	29.1	28.4	28.42	30.64	30.2	29.86	26.66	31.81	35.67	37.85
215	26.76	26.51	26.27	27.35	27.1	27.3	29	28.38	28.48	30.81	30.05	30.2	26.46	31.86	35.53	37.85
220	26.92	26.51	26.41	27.33	27.17	27.17	29.4	28.49	28.35	30.84	30.23	29.84	26.39	31.89	35.78	37.97
225	26.91	26.51	26.38	27.3	27.2	27.15	29.2	28.42	28.45	30.89	30.23	29.94	26.74	31.69	35.81	38.2
230	26.86	26.56	26.38	27.4	27.25	27.4	29.2	28.61	28.45	30.94	30.27	29.89	26.64	31.94	35.84	38.08
235	26.84	26.69	26.49	27.33	27.23	27.27	29.13	28.49	28.42	30.91	30.4	29.86	26.46	32.06	35.72	38.22
240	26.92	26.59	26.35	27.27	27.17	27.33	29.17	28.54	28.56	30.91	30.4	30.1	26.51	32.09	35.84	38.22
245	26.95	26.56	26.41	27.3	27.15	27.4	29.35	28.48	28.61	31.01	30.3	30.15	26.56	32.09	35.8	38.3
250	26.95	26.66	26.33	27.44	27.15	27.25	29.33	28.56	28.56	31.15	30.35	30.15	26.56	32.06	35.84	38.34
255	27	26.61	26.41	27.54	27.2	27.4	29.35	28.71	28.48	30.96	30.48	30.15	26.61	32.17	35.94	38.22
260	27	26.61	26.46	27.35	27.25	27.3	29.38	28.66	28.61	30.96	30.45	30.05	26.66	32.06	36.09	38.22

Table A5.4: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
265	26.92	26.44	26.44	27.37	27.27	27.46	29.38	28.64	28.54	30.89	30.42	30.08	26.64	32.09	35.96	38.3
270	27.05	26.51	26.46	27.59	27.3	27.44	29.35	28.61	28.56	30.91	30.48	30.15	26.51	32.13	35.89	38.25
275	27.05	26.66	26.46	27.49	27.3	27.4	29.38	28.66	28.49	31.08	30.48	30.08	26.79	32.17	35.86	38.41
280	26.98	26.64	26.35	27.37	27.23	27.51	29.2	28.54	28.64	31.12	30.42	30.17	26.54	32.09	36.01	38.41
285	27	26.51	26.33	27.54	27.4	27.4	29.38	28.66	28.64	31.04	30.5	30.13	26.69	32.35	36.14	38.54
290	27.05	26.71	26.51	27.49	27.44	27.44	29.4	28.61	28.76	31.1	30.59	30.25	26.66	32.33	36.04	38.54
295	27.13	26.59	26.54	27.51	27.17	27.46	29.42	28.74	28.56	31.2	30.69	30.55	26.86	32.33	36.14	38.59
300	27.08	26.74	26.49	27.46	27.23	27.51	29.5	28.79	28.76	31.38	30.52	30.3	26.81	32.22	36.16	38.61
305	27.02	26.74	26.59	27.56	27.33	27.61	29.38	28.89	28.61	31.1	30.55	30.45	26.74	32.35	36.14	38.64
310	27.1	26.71	26.51	27.54	27.3	27.44	29.4	28.86	28.86	31.2	30.64	30.5	26.71	32.2	36.19	38.59
315	27.17	26.64	26.59	27.51	27.46	27.46	29.51	28.69	28.79	31.17	30.66	30.42	26.79	32.55	36.16	38.56
320	27.15	26.66	26.61	27.69	27.44	27.54	29.54	28.76	28.69	31.27	30.64	30.38	26.64	32.4	36.39	38.64
325	27.23	26.79	26.54	27.54	27.4	27.54	29.61	28.89	28.84	31.17	30.76	30.33	26.74	32.45	36.29	38.66
330	27.15	26.71	26.41	27.54	27.4	27.4	29.61	28.86	28.84	31.33	30.66	30.38	26.64	32.5	36.39	38.61
335	27.23	26.84	26.74	27.71	27.61	27.76	29.51	29.08	28.79	31.4	30.84	30.69	26.89	32.4	36.34	38.84
340	27.25	26.71	26.56	27.54	27.59	27.59	29.66	28.96	28.84	31.42	30.71	30.61	26.54	32.6	36.11	38.81
345	27.1	26.61	26.56	27.69	27.44	27.69	29.64	28.96	28.84	31.33	30.71	30.56	26.74	32.69	36.39	38.84
350	27.02	26.64	26.44	27.56	27.42	27.51	29.59	28.91	28.74	31.42	30.79	30.61	26.54	32.55	36.34	38.84
355	27.2	26.66	26.51	27.59	27.4	27.44	29.56	29	28.81	31.35	30.74	30.55	26.56	32.66	36.41	38.64

Table A5.5: Experimental Data for Large Rashig Ring, $d_p = 3.87$ cm.
Run # 5: Re = 880.6 $Q_w = 19.8$ W/m^2 $T_{amb} = 25.0$ °C.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	25.25	25.3	25.2	25.1	25.15	25.2	25.05	25.44	25.44	25.64	25.74	25.59	25.35	25.49	25.54	25.49
5	25.23	25.33	25.13	25.23	25.23	25.23	25.17	25.17	25.49	25.54	25.64	25.59	25.64	25.64	25.54	25.54
10	25.46	25.46	25.35	25.25	25.25	25.25	25.25	25.51	25.54	25.64	25.54	25.49	25.74	25.64	25.74	25.74
15	25.39	25.35	25.2	25.25	25.3	25.25	25.39	25.3	25.46	25.71	25.61	25.46	25.61	25.66	25.98	25.88
20	25.51	25.66	25.46	25.27	25.33	25.46	25.51	25.56	25.56	25.56	25.61	25.71	25.56	25.71	25.98	26.12
25	25.54	25.44	25.39	25.27	25.33	25.33	25.39	25.44	25.46	25.66	25.86	25.51	25.56	25.76	26.15	26.05
30	25.54	25.54	25.39	25.35	25.35	25.39	25.54	25.49	25.61	25.9	25.81	25.71	25.66	25.76	26.25	26.2
35	25.51	25.41	25.36	25.33	25.27	25.41	25.36	25.61	25.59	25.74	25.79	25.69	25.79	25.88	26.17	26.27
40	25.61	25.41	25.41	25.36	25.33	25.46	25.66	25.51	25.71	25.86	25.9	25.95	25.71	25.81	26.35	26.35
45	25.59	25.49	25.44	25.39	25.3	25.49	25.64	25.59	25.79	25.88	25.79	25.74	25.64	25.64	26.33	26.27
50	25.51	25.61	25.36	25.41	25.46	25.46	25.46	25.61	25.76	25.95	25.76	25.71	25.71	25.86	26.3	26.49
55	25.61	25.51	25.46	25.56	25.46	25.51	25.46	25.51	25.84	25.79	25.84	25.69	25.74	26.02	26.46	26.51
60	25.51	25.41	25.33	25.41	25.33	25.51	25.56	25.66	25.81	26	25.9	25.71	25.71	25.86	26.51	26.56
65	25.61	25.41	25.33	25.33	25.27	25.36	25.61	25.61	25.71	25.86	25.9	25.61	25.76	26.05	26.39	26.69
70	25.51	25.61	25.46	25.33	25.41	25.56	25.56	25.61	25.71	25.9	26	25.81	25.66	26	26.59	26.74
75	25.41	25.56	25.56	25.41	25.41	25.46	25.61	25.61	25.64	26.08	25.84	25.69	25.69	26.17	26.46	26.81
80	25.61	25.46	25.41	25.41	25.41	25.41	25.66	25.71	25.79	26.08	25.98	25.98	25.59	26.08	26.51	26.81
85	25.59	25.64	25.3	25.44	25.44	25.49	25.74	25.64	25.88	26.17	25.84	25.88	25.69	26.08	26.51	26.71
90	25.76	25.41	25.27	25.33	25.41	25.46	25.81	25.76	25.98	26.02	26.02	26.02	25.69	26.17	26.61	26.86
95	25.61	25.51	25.36	25.56	25.46	25.51	25.71	25.66	25.86	26.15	25.95	25.9	25.61	26.05	26.54	26.86
100	25.69	25.59	25.39	25.39	25.49	25.69	25.74	25.84	25.84	26.12	26.02	25.92	25.79	26.23	26.61	26.86
105	25.59	25.54	25.35	25.39	25.44	25.54	25.79	25.64	25.9	26.1	26.1	25.95	25.71	26.2	26.54	26.89
110	25.66	25.56	25.36	25.46	25.46	25.61	25.66	25.81	25.74	26.12	26.12	25.88	25.64	26.17	26.66	26.76
115	25.54	25.44	25.44	25.49	25.44	25.49	25.74	25.74	25.79	26.12	26.08	25.84	25.64	26.08	26.56	26.81
120	25.46	25.51	25.41	25.46	25.36	25.51	25.66	25.66	25.74	26.02	25.84	25.79	25.74	26.08	26.76	26.91

Table A5.5: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	25.59	25.49	25.35	25.49	25.44	25.54	25.71	25.81	25.81	26.1	26	26	25.51	26	26.69	26.92
130	25.49	25.59	25.39	25.54	25.44	25.54	25.69	25.84	25.92	26.17	26.08	25.92	25.69	26.12	26.56	26.86
135	25.44	25.49	25.35	25.39	25.49	25.54	25.79	25.74	25.9	26	26	25.88	25.59	26.05	26.69	26.86
140	25.54	25.54	25.44	25.49	25.39	25.44	25.74	25.69	25.98	26.12	26.08	25.88	25.69	26.12	26.51	27
145	25.66	25.56	25.33	25.41	25.36	25.51	25.76	25.71	25.88	25.98	26.02	25.88	25.59	26.23	26.56	26.86
150	25.54	25.39	25.39	25.39	25.44	25.54	25.69	25.84	25.88	26.12	26.08	25.98	25.69	26.12	26.66	26.91
155	25.49	25.39	25.35	25.44	25.35	25.69	25.79	25.74	25.92	26.08	26.02	25.98	25.59	26.12	26.71	26.95
160	25.59	25.44	25.25	25.3	25.44	25.59	25.79	25.69	25.86	26.1	26.05	25.81	25.66	26.2	26.54	26.84
165	25.59	25.44	25.39	25.25	25.44	25.49	25.69	25.74	25.86	26	26.1	25.86	25.56	26.25	26.54	26.64
170	25.44	25.44	25.3	25.54	25.35	25.59	25.74	25.64	25.88	26.17	26.08	25.98	25.69	26.23	26.56	26.86
175	25.59	25.44	25.35	25.54	25.54	25.59	25.74	25.84	25.84	26.12	26.12	26.02	25.74	26.23	26.56	27
180	25.69	25.54	25.39	25.39	25.35	25.54	25.74	25.74	25.86	26.1	26	25.9	25.66	26.39	26.54	26.92
185	25.61	25.41	25.33	25.46	25.46	25.56	25.66	25.81	25.79	26.27	26.12	25.92	25.84	26.17	26.51	27
190	25.69	25.64	25.3	25.54	25.35	25.44	25.79	25.69	25.84	26.17	26.23	26.08	25.84	26.23	26.56	26.86
195	25.71	25.61	25.56	25.41	25.36	25.56	25.81	25.71	25.86	26.15	26	26	25.9	26.15	26.54	26.89
200	25.61	25.76	25.56	25.61	25.51	25.51	25.81	25.81	25.84	26.17	26.17	25.98	25.92	26.33	26.66	27.05
205	25.71	25.71	25.61	25.56	25.61	25.61	25.9	25.86	25.98	26.12	26.27	26.08	26.02	26.17	26.86	27.05
210	25.88	25.84	25.64	25.74	25.64	25.69	25.79	25.84	26	26.15	26.05	25.9	26.2	26.3	26.84	27.08
215	25.9	25.76	25.76	25.61	25.66	25.71	25.95	25.71	26	26.2	26.05	26	26.15	26.35	26.84	26.98
220	25.98	25.92	25.79	25.79	25.74	25.74	25.92	25.84	26.02	26.17	26.23	26.38	26.17	26.41	26.89	27.15
225	26.15	25.95	25.81	25.76	25.86	25.9	25.76	25.9	25.95	26.35	26.25	26.15	26.35	26.3	27.08	27.08
230	26.1	26	25.86	25.9	25.81	25.81	26.05	25.95	26.02	26.27	26.27	26.12	26.23	26.51	27.05	27.2
235	26.2	25.95	26	25.95	25.81	26	26.1	25.86	26.05	26.15	26.15	26.2	26.35	26.2	27.08	27.17
240	26.05	26.05	25.86	26	25.9	25.86	26.15	26.1	26.1	26.3	26.2	26.44	26.25	26.44	27.08	27.17
245	25.98	26.12	25.88	25.92	25.88	25.92	26.17	26.12	26.08	26.41	26.27	26.17	26.38	26.46	27.1	27.4
250	26.15	26.15	26.1	26.05	25.9	26.1	26.2	26.1	26.25	26.44	26.39	26.15	26.54	26.59	27.23	27.37
255	26.2	26.2	26.05	26	26.05	26	26.25	25.95	26.23	26.41	26.41	26.23	26.51	26.46	27.25	27.05
260	26.23	26.27	26.02	26.08	25.98	26.02	26.27	26.17	26.23	26.51	26.51	26.38	26.56	26.56	27.25	27.4

Table A5.5: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
265	26.38	26.27	26.08	26.17	26.02	26.08	26.27	26.23	26.27	26.56	26.46	26.17	26.41	26.61	27.3	27.49
270	26.39	26.3	26.2	26.3	26.2	26.15	26.25	26.35	26.41	26.61	26.51	26.46	26.46	26.61	27.4	27.54
275	26.35	26.35	26.15	26.2	26.15	26.35	26.44	26.49	26.3	26.69	26.54	26.59	26.44	26.64	27.42	27.51
280	26.23	26.23	26.17	26.12	26.12	26.12	26.51	26.38	26.39	26.69	26.54	26.39	26.44	26.74	27.33	27.71
285	26.25	26.3	26.25	26	26.3	26.3	26.49	26.3	26.41	26.66	26.66	26.51	26.46	26.86	27.35	27.79
290	25.98	26.12	25.98	26.02	26.12	26.17	26.41	26.17	26.33	26.71	26.61	26.51	26.17	26.71	27.4	27.59
295	26.15	26.05	25.95	26.2	26.1	26.2	26.35	26.3	26.49	26.69	26.54	26.39	26.23	26.79	27.35	27.64
300	26.17	26.08	26.08	26.12	26.02	26.12	26.41	26.41	26.39	26.74	26.54	26.49	26.2	26.74	27.3	27.64
305	26.15	26.1	26	25.95	26.1	26.15	26.2	26.3	26.41	26.56	26.66	26.51	26.17	26.76	27.3	27.59
310	26.1	26.05	25.95	26.05	26.05	26	26.35	26.2	26.41	26.71	26.66	26.33	26.23	26.81	27.27	27.66
315	26.15	25.95	25.86	26.05	26.1	26.05	26.25	26.25	26.44	26.69	26.69	26.49	26.2	26.79	27.13	27.56

Table A5.6: Experimental Data for Large Rashig Ring, $d_p = 3.87$ cm.
Run # 6: Re = 1065.9 $Q_w = 19.8\ W/m^2$ $T_{amb} = 25.0\ ^oC$.
Time in (minutes), Temperature in (^oC) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	24.9	24.95	24.85	24.81	24.85	24.81	24.9	24.9	25.08	25.23	25.23	24.87	25.17	25.08	25.17	25.13
5	25.05	25.1	24.92	24.87	24.87	24.87	24.92	24.92	25.13	25.27	25.17	25.27	25.46	25.27	25.33	25.41
10	25.33	25.23	25	25.1	25	24.95	24.95	25	25.27	25.17	25.17	25.02	25.61	25.23	25.61	25.56
15	25.41	25.3	25.1	25	24.95	25	25	25	25.23	25.17	25.27	25.23	25.76	25.36	25.86	25.61
20	25.41	25.41	25.33	25.23	25.17	25.17	25.13	25.02	25.2	25.2	25.25	25.05	25.66	25.25	25.86	25.9
25	25.54	25.64	25.54	25.2	25.25	25.3	25.25	25.25	25.3	25.44	25.35	25.35	25.88	25.44	25.98	25.92
30	25.54	25.49	25.44	25.35	25.3	25.39	25.39	25.15	25.44	25.59	25.44	25.23	25.74	25.44	26.08	25.98
35	25.51	25.56	25.56	25.41	25.41	25.51	25.33	25.33	25.46	25.51	25.61	25.41	25.95	25.41	26.17	25.95
40	25.64	25.64	25.54	25.39	25.25	25.49	25.3	25.25	25.56	25.71	25.66	25.41	25.76	25.56	26.25	26.15
45	25.66	25.66	25.61	25.61	25.33	25.46	25.51	25.36	25.61	25.76	25.71	25.51	25.81	25.61	26.44	26.35
50	25.69	25.74	25.59	25.44	25.49	25.54	25.49	25.49	25.61	25.76	25.66	25.66	25.86	25.66	26.35	26.44
55	25.79	25.69	25.54	25.54	25.49	25.59	25.59	25.49	25.64	26.02	25.79	25.64	25.92	25.79	26.56	26.46
60	25.86	25.61	25.56	25.56	25.46	25.56	25.56	25.51	25.74	25.88	25.88	25.49	26.02	25.69	26.51	26.51
65	25.79	25.79	25.64	25.69	25.59	25.54	25.74	25.54	25.74	25.88	25.92	25.49	26.02	25.88	26.51	26.51
70	25.71	25.76	25.66	25.61	25.56	25.56	25.76	25.61	25.71	26	25.86	26	25.86	25.81	26.59	26.54
75	25.84	25.79	25.64	25.64	25.69	25.64	25.88	25.69	25.86	25.95	25.86	25.95	26.05	25.86	26.59	26.69
80	25.95	25.71	25.71	25.56	25.66	25.76	25.76	25.66	25.86	26.05	26.05	25.71	25.86	25.9	26.44	26.59
85	25.88	25.79	25.74	25.74	25.69	25.79	25.84	25.79	25.86	26.2	26	25.86	26.05	25.86	26.49	26.69
90	25.9	25.95	25.86	25.66	25.71	25.71	25.9	25.86	25.95	26.15	25.95	25.9	25.9	26	26.59	26.64
95	25.95	25.81	25.76	25.81	25.81	25.71	25.86	25.81	25.92	26.12	26.12	25.92	25.92	26.02	26.71	26.81
100	25.86	25.76	25.86	25.76	25.66	25.66	25.76	25.86	26.05	26.15	26.05	26.1	25.9	26.15	26.74	26.69
105	25.98	25.88	25.74	25.79	25.79	25.79	25.88	25.84	26.1	26.25	26.2	26	26.1	26.1	26.69	26.74
110	25.92	25.92	25.81	25.86	25.81	25.76	26.02	25.92	26.12	26.17	26.08	25.98	26.02	26.02	26.86	26.91
115	25.92	25.88	25.88	25.69	25.69	25.92	25.98	25.88	26	26.25	26.25	25.81	26.2	26.2	26.84	26.84
120	25.92	25.92	25.69	25.88	25.69	25.84	26.02	25.98	26	26.25	26.25	26.1	26.2	26.3	26.89	26.79

Table A5.6: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	26	25.95	25.76	25.76	25.76	25.86	26	25.95	26.08	26.27	26.17	26.12	25.98	26.27	26.86	26.91
130	26	25.95	25.86	25.86	25.81	25.86	25.95	25.95	26.23	26.23	26.23	26.12	26.17	26.27	26.91	26.95
135	25.98	25.98	25.79	25.84	25.69	25.92	26.08	25.98	26.2	26.2	26.2	26.2	26.15	26.35	26.89	26.89
140	26	25.92	25.79	26	25.88	26	25.92	25.92	26.1	26.25	26.3	26.35	26.15	26.35	26.89	27.02
145	26.12	26.02	25.84	25.88	25.79	25.88	25.98	26.02	26.1	26.39	26.35	26.3	26.3	26.35	26.92	27.13
150	26.1	26	25.81	25.9	25.86	25.95	25.95	26.05	26.17	26.38	26.33	26.33	26.08	26.33	26.91	26.91
155	25.98	26.08	25.92	25.88	25.84	25.84	25.84	25.98	26.3	26.39	26.3	26.15	26.2	26.44	27.08	26.89
160	26.2	26.05	25.95	25.86	25.95	26	26.15	26.1	26.12	26.41	26.33	26.23	26.23	26.51	26.86	27.2
165	26.1	26.1	25.95	25.76	25.86	26	26.3	26	26.33	26.56	26.38	26.12	26.27	26.46	26.91	27.23
170	26.08	26.17	26.12	25.92	25.98	26.08	26.08	26.23	26.12	26.56	26.51	26.23	26.33	26.23	26.91	27.23
175	26.23	26.12	25.98	25.98	26.08	26.08	26.23	26.17	26.2	26.39	26.49	26.2	26.35	26.39	26.92	27.17
180	26.25	26.15	26.05	25.92	26	26.1	26.2	26.25	26.3	26.49	26.44	26.3	26.35	26.44	27.13	27.08
185	26.33	26.17	26.08	26.12	26.08	26.08	26.23	26.38	26.33	26.56	26.56	26.12	26.46	26.46	27.05	27.1
190	26.38	26.23	26.27	26.23	26.02	26.08	26.23	26.17	26.27	26.46	26.46	26.27	26.33	26.51	27.1	27.2
195	26.27	26.33	26.12	26.12	26.12	26.12	26.17	26.23	26.38	26.66	26.38	26.38	26.51	26.66	27.15	27.2
200	26.38	26.27	26.12	26.12	26.12	26.17	26.27	26.27	26.35	26.64	26.49	26.44	26.54	26.49	27.27	27.27
205	26.38	26.23	26.12	26.12	26.12	26.23	26.46	26.33	26.44	26.69	26.54	26.39	26.54	26.54	27.23	27.17
210	26.39	26.15	26.15	26.2	26.15	26.15	26.35	26.3	26.35	26.64	26.49	26.39	26.59	26.69	27.23	27.33
215	26.41	26.27	26.17	26.27	26.23	26.27	26.41	26.33	26.39	26.74	26.64	26.44	26.59	26.64	27.27	27.27
220	26.38	26.33	26.17	26.17	26.23	26.33	26.46	26.27	26.44	26.69	26.59	26.39	26.54	26.64	27.13	27.3
225	26.56	26.38	26.33	26.33	26.27	26.27	26.41	26.38	26.49	26.74	26.74	26.25	26.54	26.74	27.33	27.33
230	26.41	26.17	26.27	26.23	26.33	26.17	26.46	26.38	26.74	26.74	26.64	26.69	26.49	26.84	27.27	27.37
235	26.49	26.2	26.25	26.3	26.25	26.2	26.49	26.39	26.51	26.91	26.66	26.71	26.56	26.76	27.4	27.44
240	26.39	26.3	26.35	26.2	26.25	26.35	26.44	26.39	26.51	26.66	26.66	26.38	26.51	26.71	27.27	27.42
245	26.35	26.35	26.3	26.25	26.2	26.3	26.49	26.25	26.59	26.74	26.69	26.64	26.44	26.79	27.23	27.37
250	26.44	26.39	26.2	26.25	26.25	26.3	26.44	26.44	26.51	26.81	26.76	26.41	26.51	26.76	27.35	27.4
255	26.46	26.41	26.23	26.27	26.17	26.27	26.56	26.46	26.66	26.81	26.81	26.71	26.46	26.86	27.2	27.44
260	26.41	26.33	26.23	26.33	26.23	26.27	26.56	26.41	26.56	26.86	26.61	26.61	26.61	26.81	27.4	27.49

Table A5.7: Experimental Data for Large Rashig Ring, $d_p = 3.87$ cm.
Run # 7: Re = 672.6 $Q_w = 179.2$ W/m^2 $T_{amb} = 24.5$ °C.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	24.85	24.85	24.66	24.36	24.46	24.51	24.61	24.61	24.87	24.92	25.08	24.69	25.08	24.98	24.92	25.08
5	24.79	24.92	24.87	24.69	24.64	24.64	24.79	24.69	24.87	25.13	25.02	24.92	25.13	24.98	26.17	26.08
10	24.95	24.81	24.76	24.66	24.66	24.85	24.81	24.81	24.92	25.08	25.13	24.79	25.17	25.08	27.42	27.2
15	25.13	24.92	25.08	25.08	24.92	24.83	25.36	25.08	25.08	25.61	25.27	25.13	25.36	25.61	28.49	28.45
20	25.23	25.02	24.87	25.23	24.98	25.08	25.41	25.13	25.15	25.76	25.3	25.2	25.3	25.71	29.35	29.08
25	25.33	25.13	24.98	25.36	25.23	25.27	25.76	25.41	25.33	26.02	25.84	25.59	25.41	26.23	30.38	30.23
30	25.39	25.1	25	25.64	25.3	25.2	26.12	25.59	25.44	26.41	25.88	25.79	25.25	26.38	30.96	31.01
35	25.39	25.39	25.13	25.79	25.54	25.49	26.44	25.79	25.71	26.84	26.3	26	25.46	26.79	31.64	32.11
40	25.54	25.35	25.1	25.88	25.64	25.69	26.56	26.02	25.66	27.05	26.59	26.35	25.41	27.1	32.3	32.55
45	25.64	25.3	25.3	25.98	25.74	25.74	26.81	26.12	25.92	27.35	27.05	26.71	25.54	27.3	32.63	33.09
50	25.86	25.33	25.13	25.95	25.76	25.76	27.08	26.35	26.15	27.64	27.13	26.79	25.61	27.79	33.2	33.79
55	25.81	25.41	25.25	26.1	25.95	25.9	27.35	26.64	26.3	27.98	27.42	27.08	25.46	27.98	33.67	34.3
60	25.86	25.27	25.27	26.2	25.86	26	27.46	26.79	26.35	28.13	27.61	27.27	25.36	28.33	33.84	34.76
65	25.84	25.25	25.39	26.23	25.92	26.12	27.74	26.81	26.51	28.49	27.69	27.49	25.49	28.59	34.28	35.11
70	25.79	25.49	25.15	26.17	26.08	26.02	27.66	27	26.61	28.49	28	27.81	25.15	28.91	34.33	35.5
75	25.88	25.39	25.15	26.23	26.23	26.27	27.81	27.1	26.74	28.86	28.17	27.91	25.41	29.05	34.72	35.81
80	25.86	25.36	25.17	26.39	26.05	26.1	27.91	27.08	26.84	29.05	28.4	28.15	25.15	29.2	34.81	36.29
85	25.86	25.44	25.25	26.25	26.2	26.2	27.98	27.3	27	29.3	28.69	28.25	25.35	29.54	35.06	36.5
90	25.84	25.54	25.35	26.35	26.2	26.2	28.23	27.35	27	29.35	28.81	28.3	25.35	29.76	35.19	37
95	26.08	25.39	25.39	26.56	26.33	26.23	28.17	27.35	27	29.45	28.84	28.4	25.25	29.89	35.25	37.03
100	25.92	25.44	25.15	26.46	26.38	26.33	28.4	27.35	27.13	29.71	28.96	28.71	25.27	30.08	35.45	37.26
105	25.86	25.46	25.23	26.44	26.2	26.2	28.33	27.61	27.13	29.71	29.08	28.66	25.27	30.33	35.67	37.64
110	25.84	25.39	25.25	26.51	26.46	26.51	28.42	27.74	27.33	29.76	29.25	28.91	25.35	30.52	35.8	37.72
115	25.98	25.44	25.1	26.61	26.38	26.41	28.54	27.59	27.37	30.01	29.25	29.15	25.33	30.71	35.8	37.9
120	25.98	25.49	25.2	26.59	26.39	26.44	28.61	27.69	27.56	30.2	29.45	29.15	25.35	30.76	35.84	38.05

Table A5.7: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	26	25.54	25.25	26.54	26.44	26.49	28.66	27.89	27.54	30.3	29.64	28.99	25.49	30.96	35.94	38.33
130	26.02	25.54	25.3	26.51	26.46	26.46	28.56	27.84	27.61	30.33	29.71	29.33	25.46	30.99	36.01	38.34
135	25.92	25.44	25.3	26.59	26.44	26.54	28.66	27.84	27.51	30.38	29.61	29.42	25.51	31.12	36.29	38.34
140	26.08	25.44	25.25	26.61	26.61	26.51	28.69	27.98	27.61	30.48	29.71	29.42	25.33	31.35	36.29	38.44
145	26	25.36	25.33	26.54	26.44	26.49	28.86	27.81	27.79	30.56	29.86	29.42	25.41	31.5	36.5	38.61
150	26.12	25.44	25.25	26.76	26.46	26.61	28.79	28.02	27.89	30.64	29.79	29.51	25.23	31.5	36.31	38.79
155	25.95	25.41	25.23	26.64	26.49	26.64	28.86	28.1	27.95	30.66	29.96	29.54	25.3	31.64	36.39	38.59
160	26.02	25.56	25.23	26.66	26.41	26.56	28.79	28.15	27.94	30.64	30.04	29.64	25.39	31.71	36.53	38.86
165	25.92	25.44	25.25	26.56	26.46	26.46	28.84	28.17	27.84	30.86	30.15	29.84	25.39	31.71	36.31	38.91
170	26.05	25.49	25.2	26.64	26.44	26.59	28.76	28.08	27.86	30.89	30.23	29.76	25.46	31.74	36.5	38.97
175	25.88	25.39	25.44	26.69	26.49	26.44	28.91	28.23	28.02	30.59	30.08	29.69	25.41	32.13	36.45	38.95
180	26.05	25.36	25.27	26.64	26.59	26.64	28.81	28.15	28.02	30.84	30.23	29.71	25.36	31.86	36.55	39
185	26.02	25.54	25.35	26.61	26.46	26.56	28.89	28.17	28	31.01	30.2	29.79	25.3	31.89	36.47	39.03
190	26	25.46	25.41	26.64	26.54	26.59	28.91	28.23	28.02	30.84	30.17	29.84	25.39	32.09	36.53	39.05
195	26.02	25.49	25.35	26.76	26.61	26.66	28.84	28.13	28.1	30.96	30.4	29.89	25.44	32.09	36.63	39.3
200	25.98	25.49	25.35	26.66	26.41	26.61	29.08	28.23	28.05	30.96	30.3	29.94	25.49	32.13	36.7	39.45
205	26.08	25.54	25.25	26.71	26.56	26.61	29.13	28.23	28.05	30.86	30.3	29.91	25.33	32.3	36.7	39.35
210	26	25.46	25.36	26.64	26.59	26.64	29	28.42	28.17	31.17	30.48	30.04	25.36	32.3	36.92	39.42
215	26.02	25.59	25.35	26.76	26.66	26.81	29.17	28.4	28.08	31.25	30.59	30.13	25.44	32.42	36.9	39.55
220	26.1	25.51	25.36	26.84	26.64	26.64	28.91	28.35	28.05	31.04	30.48	30.05	25.51	32.35	36.83	39.59
225	26.05	25.51	25.3	26.79	26.64	26.79	29	28.33	28.17	31.12	30.52	30.13	25.56	32.47	36.72	39.59
230	26.17	25.39	25.35	26.71	26.56	26.56	29.02	28.35	28.15	31.23	30.48	30.17	25.66	32.35	37.05	39.74
235	26.05	25.36	25.41	26.84	26.54	26.74	29	28.42	28.05	31.27	30.52	30.2	25.54	32.5	37.08	39.69
240	26.08	25.54	25.39	26.95	26.66	26.71	29.13	28.49	28.2	31.33	30.76	30.1	25.49	32.6	37.11	39.89
245	26.1	25.56	25.33	26.79	26.64	26.79	29.15	28.35	28.15	31.38	30.55	30.2	25.44	32.55	37.11	39.89
250	26.17	25.69	25.39	26.91	26.61	26.76	29.27	28.48	28.3	31.33	30.59	30.3	25.49	32.55	37.16	39.89
255	26.02	25.54	25.39	26.71	26.61	26.76	29.13	28.54	28.2	31.42	30.66	30.25	25.61	32.81	37.11	39.84
260	26.2	25.56	25.46	26.98	26.74	26.69	29.3	28.59	28.35	31.45	30.64	30.4	25.49	32.69	37.09	39.99

Table A5.7: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
265	26.1	25.61	25.27	26.84	26.64	26.69	29.2	28.42	28.33	31.45	30.74	30.23	25.39	32.74	37.14	39.86
270	26.3	25.61	25.27	26.84	26.64	26.79	29.25	28.45	28.54	31.38	30.66	30.45	25.49	32.74	37.16	39.99
275	26.08	25.54	25.44	26.71	26.66	26.71	29.13	28.59	28.25	31.42	30.81	30.35	25.35	32.84	37.05	39.94
280	25.98	25.46	25.36	26.81	26.66	26.76	29.33	28.64	28.35	31.4	30.79	30.35	25.49	32.89	37.16	39.99

Table A5.8: Experimental Data for Large Rashig Ring, $d_p = 3.87$ cm.
Run # 8: Re = 447.4 $Q_w = 179.2$ W/m^2 $T_{amb} = 25.0$ °C.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	24.98	25.13	24.98	24.98	25.02	25.13	25.13	25.51	25.84	25.69	25.79	25.64	24.71	25.84	25.39	25.54
5	24.98	24.83	24.83	24.98	24.92	25.08	25.17	25.23	25.69	25.64	25.74	25.69	25.2	25.79	26.38	26.64
10	25.23	24.98	24.98	25.08	25.02	25.17	25.36	25.36	25.88	25.74	25.88	25.56	25.17	26.12	27.86	27.86
15	25.17	24.87	24.98	25.23	25.08	25.17	25.56	25.46	25.84	26.08	25.98	25.92	25.44	26.23	28.94	29.08
20	25.27	25.13	24.98	25.23	25.17	25.41	25.95	25.61	25.79	26.25	26.3	25.88	25.25	26.39	30.15	30.2
25	25.35	25.2	25	25.59	25.44	25.35	26.08	25.79	25.98	26.76	26.41	26.02	25.13	26.71	31.1	31.25
30	25.56	25.17	25.13	25.86	25.46	25.56	26.49	25.95	26.05	26.91	26.66	26.39	25.51	27.05	32.11	32.22
35	25.66	25.27	24.98	26	25.66	25.71	26.79	26.2	26.08	27.42	26.95	26.56	25.2	27.37	32.86	33.16
40	25.71	25.3	25.3	26.05	25.9	25.76	27.15	26.51	26.27	27.69	27.25	26.81	25.17	27.69	33.67	33.89
45	25.76	25.27	25.13	26.3	26.15	25.86	27.33	26.64	26.41	28.2	27.49	27	25.3	27.91	34.25	34.89
50	25.81	25.33	25.08	26.39	26	26	27.56	26.84	26.49	28.48	27.84	27.02	25.17	28.42	34.65	35.5
55	25.86	25.56	25.27	26.49	26.3	26.15	27.94	26.98	26.84	28.66	28.13	27.42	25.13	28.71	35.16	36.19
60	25.92	25.49	25.3	26.61	26.33	26.17	28.27	27.2	26.91	29.1	28.4	27.89	25.49	29.15	35.86	36.83
65	25.9	25.27	25.17	26.69	26.54	26.39	28.4	27.37	27.02	29.17	28.64	28.02	25.13	29.33	36.11	37.41
70	25.98	25.35	25.35	26.81	26.56	26.51	28.59	27.49	27.3	29.76	29	28.25	25.1	29.81	36.72	37.9
75	26	25.25	25.2	26.89	26.54	26.64	28.56	27.59	27.3	29.89	29.02	28.38	25.17	29.89	37.03	38.39
80	25.95	25.33	25.36	27.02	26.69	26.69	28.91	27.71	27.54	30.3	29.45	28.59	25.39	30.3	37.19	38.89
85	26.1	25.36	25.23	27.13	26.71	26.61	28.99	27.95	27.51	30.42	29.66	28.96	25.27	30.61	37.7	39.38
90	26.05	25.36	25.1	27.08	26.89	26.74	29.35	28.15	27.64	30.61	29.86	28.84	25.3	30.91	38	39.86
95	26.05	25.51	25.27	27.23	26.81	26.91	29.45	28.25	27.81	31.06	30.01	29.45	25.25	31.12	38.39	40.09
100	26.05	25.46	25.23	27.27	26.92	26.84	29.4	28.35	27.94	31.12	30.33	29.38	25.41	31.5	38.56	40.6
105	26.23	25.64	25.44	27.3	27	26.81	29.48	28.48	28.02	31.3	30.5	29.84	25.33	31.71	38.74	40.83
110	26.17	25.51	25.33	27.4	27.1	27	29.79	28.69	28.2	31.69	30.71	29.71	25.33	31.94	38.89	41.19
115	26.17	25.59	25.3	27.33	26.92	27.02	29.81	28.56	28.13	31.86	30.79	29.84	25.2	32.06	39.05	41.47
120	26.15	25.56	25.33	27.46	27.13	27.08	29.94	28.79	28.48	31.94	31.17	30.23	25.27	32.4	39.15	41.83

Table A5.8: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	26.27	25.64	25.3	27.49	26.95	27.15	29.91	28.81	28.49	32.17	31.15	30.35	25.3	32.6	39.22	41.75
130	26.23	25.61	25.33	27.4	27.05	27.1	29.99	28.94	28.61	32.2	31.23	30.48	25.17	32.76	39.2	41.83
135	26.17	25.59	25.33	27.35	27.2	27.1	30.33	29.02	28.71	32.37	31.35	30.52	25.3	33.09	39.25	41.95
140	26.33	25.59	25.25	27.44	27.1	27.2	30.25	29.05	28.61	32.25	31.45	30.61	25.1	33.14	39.25	42.26
145	26.23	25.54	25.39	27.35	27.15	27.25	30.05	29.1	28.76	32.5	31.6	30.66	25.36	33.22	39.17	42.19
150	26.25	25.49	25.39	27.42	27.33	27.23	30.15	29.2	28.84	32.63	31.74	30.74	25.79	33.4	39.53	42.36
155	26.35	25.56	25.46	27.56	27.37	27.17	30.13	29.27	28.84	32.63	31.64	30.99	25.64	33.67	39.47	42.41
160	26.3	25.79	25.54	27.51	27.23	27.27	30.45	29.2	29	32.79	31.86	31.1	25.61	33.62	39.59	42.7
165	26.41	25.74	25.49	27.49	27.4	27.3	30.25	29.2	28.84	32.76	32.01	30.89	25.59	33.79	39.61	42.58
170	26.23	25.71	25.56	27.59	27.35	27.44	30.35	29.33	29.02	32.91	31.94	31.38	25.69	33.89	39.76	42.85
175	26.39	25.61	25.56	27.76	27.33	27.42	30.42	29.33	29	33.01	32.13	31.15	25.81	34.14	39.69	42.75
180	26.35	25.79	25.49	27.81	27.37	27.33	30.55	29.35	29.08	32.96	32.15	31.23	25.54	34.01	39.76	42.95
185	26.44	25.76	25.59	27.71	27.46	27.46	30.52	29.5	29.17	33.3	32.15	31.4	25.76	34.22	39.76	43.06
190	26.41	25.79	25.69	27.81	27.51	27.42	30.55	29.54	29.2	33.11	32.22	31.66	25.69	34.4	40.06	42.97
195	26.56	25.92	25.71	27.79	27.54	27.54	30.61	29.71	29.33	33.14	32.37	31.6	25.81	34.42	39.99	43.16
200	26.59	25.9	25.81	27.69	27.44	27.44	30.52	29.51	29.25	33.25	32.17	31.61	25.69	34.5	39.96	43.14
205	26.61	25.92	25.84	28.02	27.59	27.59	30.64	29.64	29.45	33.35	32.53	31.66	25.9	34.7	40.04	43.39
210	26.51	25.88	25.79	27.84	27.44	27.59	30.69	29.74	29.56	33.47	32.5	31.84	25.84	34.72	40.09	43.49
215	26.56	25.98	25.74	27.89	27.64	27.69	30.74	29.74	29.51	33.53	32.6	31.74	26.02	34.86	40.14	43.54
220	26.74	26.05	25.81	27.86	27.56	27.46	30.71	29.71	29.54	33.47	32.6	31.76	25.92	34.76	40.16	43.58
225	26.61	26.05	25.76	27.94	27.69	27.79	30.76	29.81	29.5	33.58	32.74	31.76	25.69	34.86	40.16	43.58
230	26.74	25.92	25.88	27.95	27.56	27.66	30.84	29.89	29.61	33.69	32.76	31.84	25.88	35.09	40.4	43.65
235	26.79	25.9	25.86	27.94	27.64	27.69	30.91	29.86	29.69	33.76	32.84	32.09	25.95	35.06	40.21	43.85
240	26.54	26	25.81	28	27.71	27.81	30.89	29.89	29.84	33.74	32.81	32.06	25.76	35.16	40.19	43.83
245	26.71	26.1	25.81	27.94	27.69	27.69	30.96	29.86	29.71	33.94	32.96	32.13	25.69	35.14	40.21	43.72
250	26.74	26.1	25.86	28	27.71	27.66	31.04	29.94	29.64	33.84	32.96	32.15	25.95	35.4	40.4	43.87
255	26.71	26.05	25.95	28.08	27.79	27.79	31.01	30.01	29.76	33.96	33.04	32.13	26.02	35.28	40.47	43.9
260	26.71	26.23	25.88	28.05	27.86	27.86	30.99	30.08	29.69	33.89	33.17	32.35	25.86	35.58	40.4	44.1

Table A5.8: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
265	26.76	26.12	25.98	28.08	27.74	27.84	30.99	29.99	29.79	33.86	33.04	32.11	25.95	35.58	40.62	44.1
270	26.84	26.08	25.88	28.15	27.91	27.91	31.17	30.23	29.86	33.96	33.09	32.17	26.12	35.58	40.62	44.16
275	26.81	26.08	26.02	28.02	27.94	27.89	31.3	30.25	29.89	34.16	33.14	32.47	26.1	35.58	40.8	44.05
280	26.84	26.27	26.08	28.15	27.86	27.91	31.27	30.13	29.86	34.09	32.99	32.47	26.02	35.7	40.7	44.31
285	27	26.33	25.92	28.2	27.86	27.86	31.17	30.13	29.96	34.28	33.4	32.37	26.2	35.72	40.67	44.31
290	27.02	26.23	25.98	28.25	28	28	31.17	30.23	29.86	34.09	33.35	32.64	26.23	35.8	40.75	44.44
295	26.95	26.23	26.1	28.13	28.08	28.02	31.25	30.2	29.99	34.25	33.33	32.45	26.25	35.78	40.86	44.51
300	26.92	26.41	25.98	28.2	28.05	28.05	31.38	30.27	30.01	34.28	33.4	32.47	25.92	36.01	40.89	44.65
305	27	26.38	26.02	28.38	27.94	27.94	31.45	30.45	30.17	34.14	33.42	32.64	26	36.01	40.86	44.56
310	27.08	26.3	26	28.42	28.02	28.08	31.35	30.55	30.04	34.35	33.38	32.71	25.76	35.91	40.94	44.63
315	27.02	26.3	26.15	28.33	27.89	28.02	31.2	30.5	30.01	34.42	33.5	32.79	26.02	36.04	40.94	44.7
320	27	26.2	26.05	28.23	28.02	28.08	31.45	30.64	30.17	34.45	33.53	32.91	25.95	36.16	41.24	44.83
325	26.95	26.33	26.02	28.27	28.02	28.08	31.4	30.55	30.15	34.42	33.5	32.79	26.08	36.26	41.01	44.7
330	26.95	26.3	26	28.38	28.08	28.13	31.55	30.4	30.15	34.42	33.69	32.63	25.84	36.26	41.26	45.1
335	27	26.2	25.9	28.33	28.27	28.13	31.55	30.5	30.27	34.55	33.71	33.01	25.92	36.44	41.24	45.12
340	27.02	26.2	26	28.42	28.02	28.08	31.6	30.55	30.15	34.6	33.71	32.74	25.79	36.31	41.34	45.26
345	27.1	26.17	25.98	28.38	28.23	28.13	31.64	30.59	30.42	34.7	33.86	32.89	25.88	36.47	41.5	45.26
350	26.91	26.17	25.92	28.4	28.1	28.15	31.58	30.52	30.38	34.81	33.84	32.86	25.81	36.55	41.36	45.29
355	26.91	26.15	26	28.42	28.13	28.13	31.64	30.59	30.38	34.7	33.81	33.06	25.86	36.65	41.46	45.34
360	26.95	26.1	25.9	28.38	28.17	28.17	31.79	30.74	30.33	34.81	33.89	33.06	25.9	36.65	41.53	45.36
365	27.05	26.17	25.95	28.38	28.13	28.17	31.74	30.69	30.48	34.96	34.04	32.79	25.92	36.75	41.41	45.39
370	26.92	26.15	26	28.33	28.02	28.13	31.69	30.64	30.4	34.96	34.09	33.4	25.92	36.75	41.5	45.39
375	26.84	26.17	26.08	28.35	28.2	28.15	31.66	30.76	30.42	34.91	33.99	33.16	25.86	36.75	41.62	45.64
380	26.98	26.05	25.95	28.4	28.15	28.1	31.55	30.86	30.59	34.94	34.11	33.14	25.95	36.83	41.53	45.49

Table A5.9: Experimental Data for Large Rashig Ring, $d_p = 3.87$ cm.
Run # 9: Re = 672.6 $Q_w = 79.4\ W/m^2$ $T_{amb} = 25.0\ ^oC$.
Time in (minutes), Temperature in (^oC) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	25.02	24.98	25.02	24.66	24.87	24.87	25.02	25.23	25.51	25.51	25.46	25.36	25.3	25.66	25.41	25.46
5	25.05	25.1	25.05	25.05	24.81	24.95	24.95	25.05	25.39	25.49	25.59	25.54	25.59	25.59	25.74	25.84
10	25.2	25.15	25.05	25.1	25	25.15	25.15	25.2	25.51	25.56	25.66	25.51	25.51	25.76	26.44	26.49
15	25.3	25.2	25.05	25.1	25	25	25.3	25.3	25.64	25.64	25.64	25.44	25.64	25.74	26.91	26.91
20	25.36	25.36	25.17	25.33	25.08	25.13	25.46	25.46	25.44	25.92	25.64	25.69	25.74	25.92	27.46	27.61
25	25.61	25.51	25.33	25.33	25.27	25.23	25.56	25.46	25.64	25.98	25.88	25.79	25.69	26.08	28	27.95
30	25.71	25.56	25.36	25.46	25.41	25.41	25.86	25.66	25.71	26.12	25.98	25.81	25.9	26.38	28.3	28.4
35	25.64	25.59	25.35	25.54	25.54	25.49	25.92	25.64	25.79	26.27	26.17	26.12	25.88	26.41	28.76	28.76
40	25.84	25.64	25.44	25.74	25.69	25.64	26.23	25.92	25.84	26.56	26.33	26.12	25.98	26.66	28.89	29.1
45	25.9	25.66	25.46	25.66	25.61	25.66	26.1	25.9	25.88	26.66	26.46	26.08	25.64	26.71	29.02	29.25
50	25.88	25.69	25.39	25.84	25.69	25.84	26.41	26.02	26.1	26.89	26.49	26.39	25.81	26.98	29.33	29.66
55	25.9	25.71	25.66	25.9	25.86	25.81	26.39	25.95	26.27	26.91	26.66	26.41	26.02	26.91	29.45	29.84
60	25.92	25.69	25.64	25.92	25.88	25.88	26.61	26.33	26.17	27.15	26.86	26.71	25.98	27.2	29.74	30.08
65	26	25.81	25.56	26.05	25.9	25.95	26.59	26.25	26.17	27.2	26.91	26.61	26.08	27.2	29.84	30.4
70	26	25.71	25.51	26	25.95	26.05	26.74	26.39	26.33	27.35	26.91	26.66	26.08	27.44	29.99	30.4
75	26	25.76	25.56	25.9	25.95	26.1	26.84	26.49	26.44	27.37	27.13	26.98	25.76	27.56	30.01	30.61
80	26.12	25.92	25.64	26.08	25.98	26.12	26.91	26.56	26.49	27.56	27.23	27.08	25.81	27.61	30.25	30.81
85	25.92	25.84	25.64	26.02	25.98	25.98	26.81	26.61	26.54	27.51	27.23	27.13	25.86	27.56	30.23	30.81
90	25.98	25.88	25.69	26.08	26.02	26.08	27	26.61	26.59	27.76	27.37	27.13	25.81	27.91	30.4	30.96
95	26.08	25.74	25.64	26.17	25.98	25.98	26.91	26.56	26.61	27.64	27.35	27.15	26.02	27.91	30.35	31.15
100	25.98	25.88	25.88	26.12	26.12	26.12	27	26.71	26.61	27.84	27.54	27.3	25.88	27.98	30.52	31.12
105	26.12	25.88	25.64	26.17	26.17	26.12	27	26.76	26.74	27.91	27.51	27.08	26.05	27.95	30.56	31.48
110	26.08	25.81	25.56	26.12	26.08	26.12	27.15	26.81	26.76	27.89	27.64	27.35	25.98	28.23	30.64	31.5
115	26.05	25.86	25.61	26.15	26	26.1	26.98	26.79	26.79	27.95	27.66	27.37	25.81	28.25	30.55	31.48
120	26.08	25.79	25.74	26.23	26.12	26.17	27.17	26.86	26.79	28.05	27.71	27.56	25.95	28.25	30.71	31.66

Table A5.9: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	26	25.9	25.81	26.25	26.15	26.3	27.23	26.98	26.74	28.05	27.71	27.56	25.9	28.38	30.71	31.58
130	26.12	25.74	25.64	26.17	26.08	26.17	27.17	26.79	26.81	28.15	27.56	27.76	25.86	28.45	30.74	31.66
135	25.92	25.88	25.79	26.17	26.17	26.33	27.2	26.95	26.98	28.15	27.76	27.61	26	28.45	30.66	31.71
140	25.88	25.88	25.44	26.08	25.98	26.17	27.25	26.81	26.95	28.15	27.86	27.56	25.71	28.49	30.64	31.81
145	26.08	25.79	25.69	26.23	26.17	26.33	27.17	26.92	26.98	28.27	27.79	27.74	25.86	28.56	30.56	31.89
150	25.98	25.79	25.66	26.17	26.02	26.23	27.2	27	26.91	28.23	27.94	27.74	25.79	28.66	30.79	31.74
155	25.95	25.81	25.61	26.3	26.15	26.3	27.17	26.92	27.05	28.27	28.08	27.74	26.02	28.66	30.84	31.94
160	26	25.81	25.66	26.2	26.1	26.15	27.25	26.95	26.95	28.38	27.98	27.69	25.79	28.61	30.84	31.89
165	26	25.76	25.71	26.35	26.05	26.25	27.27	26.98	27.13	28.3	27.86	27.76	26.05	28.71	30.91	31.99
170	26.12	25.74	25.74	26.27	26.17	26.23	27.1	27.05	26.98	28.17	27.76	27.61	25.76	28.66	30.66	31.84
175	25.95	25.71	25.76	26.05	26.1	26.25	27.23	26.92	27.05	28.23	27.98	27.84	25.84	28.69	30.69	32.06
180	26.05	25.66	25.71	26.27	26.12	26.12	27.2	27.05	26.92	28.25	28	27.76	25.86	28.76	30.76	31.89
185	25.88	25.88	25.69	26.12	26.23	26.27	27.4	27	26.92	28.33	28.02	27.79	26	28.71	30.81	31.94
190	25.95	26	25.61	26.2	26.25	26.2	27.23	27.13	27.08	28.4	28.05	27.81	26	28.74	30.64	32.13
195	26.1	25.74	25.79	26.25	26.2	26.25	27.27	27.02	27.02	28.35	28.1	27.76	26	28.69	30.64	32.01
200	26.15	25.74	25.69	26.25	26.3	26.1	27.37	27.02	27.05	28.33	28.02	27.94	25.92	28.74	30.79	32.06
205	26.02	25.9	25.76	26.27	26.17	26.33	27.35	26.86	27.02	28.35	28.05	27.81	25.95	28.81	30.96	31.99
210	26.05	25.9	25.66	26.2	26.2	26.3	27.27	27.13	27.17	28.4	28.1	27.76	26	28.89	30.89	32.11
215	26.02	25.79	25.79	26.35	26.2	26.3	27.23	27.08	27.15	28.42	28.02	28.17	25.98	29.05	30.81	31.94
220	26.08	25.81	25.71	26.33	26.27	26.38	27.35	26.95	27.17	28.45	28.05	27.95	25.95	28.99	30.99	32.01
225	26.2	25.81	25.66	26.39	26.2	26.35	27.37	27.17	27.2	28.38	28.17	27.98	26.08	29	30.91	32.04
230	26.15	25.9	25.81	26.25	26.25	26.3	27.44	27.05	27.08	28.48	28.23	27.98	25.98	28.91	31.01	32.17
235	26.1	25.9	25.76	26.35	26.35	26.44	27.42	27.13	27.25	28.45	28.13	27.84	25.92	28.94	30.99	32.2
240	26.15	25.9	25.66	26.39	26.3	26.35	27.46	27.08	27.15	28.42	28.13	27.98	25.92	28.99	30.71	32.25
245	26.17	25.88	25.71	26.27	26.38	26.27	27.4	27.1	27.25	28.42	28.17	27.89	26.02	29.08	31.04	32.13
250	26.23	25.79	25.69	26.23	26.27	26.33	27.37	27.13	27.27	28.4	28.05	28.05	25.86	28.99	31.04	32.25
255	26.1	25.95	25.81	26.3	26.05	26.3	27.37	27.08	27	28.56	28.33	27.98	25.98	28.94	30.94	32.09
260	26.33	25.92	25.74	26.33	26.33	26.33	27.51	27.13	27.15	28.51	28.23	27.89	26.08	29.02	31.04	32.3

Table A5.10: Experimental Data for Large Rashig Ring, $d_p = 3.87$ cm.
Run # 10: Re = 447.4 $Q_w = 79.4$ W/m^2 $T_{amb} = 25.2$ °C.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	25.3	25.3	25.39	25.3	25.25	25.2	25.39	25.39	25.61	25.76	25.71	25.71	25.51	25.71	25.76	25.86
5	25.25	25.3	25.25	25.1	25.15	25.3	25.2	25.2	25.49	25.64	25.74	25.39	25.64	25.69	26.23	26.23
10	25.25	25.44	25.39	25.2	25.39	25.25	25.35	25.3	25.56	25.71	25.81	25.76	25.66	25.76	26.81	26.81
15	25.36	25.46	25.17	25.33	25.23	25.23	25.46	25.36	25.49	25.86	25.81	25.49	25.76	25.9	27.17	27.35
20	25.59	25.44	25.39	25.49	25.3	25.39	25.69	25.64	25.61	25.95	25.9	25.71	26	26.05	27.98	27.98
25	25.46	25.46	25.41	25.66	25.41	25.36	25.76	25.56	25.71	26.17	25.98	25.76	25.76	26.08	28.45	28.25
30	25.74	25.59	25.39	25.79	25.69	25.54	26.02	25.64	25.79	26.33	26.08	25.64	25.64	26.46	28.96	29
35	25.56	25.51	25.27	25.81	25.56	25.46	26.1	25.71	25.9	26.51	26.25	25.95	25.61	26.51	29.35	29.3
40	25.66	25.56	25.41	25.66	25.76	25.66	26.15	25.9	25.98	26.51	26.33	26.08	25.59	26.66	29.51	29.56
45	25.61	25.51	25.36	25.9	25.71	25.71	26.39	26	25.9	26.79	26.44	26.25	25.66	26.98	29.84	29.84
50	25.84	25.54	25.54	25.98	25.74	25.92	26.56	26.08	25.98	26.92	26.61	26.41	25.64	27.02	29.99	30.33
55	25.88	25.44	25.44	25.92	25.79	25.74	26.51	26.23	26.1	27.08	26.69	26.39	25.81	27.08	30.08	30.64
60	25.81	25.86	25.54	25.9	25.95	25.81	26.59	26.15	26.3	27.35	27.02	26.64	26.05	27.13	30.55	30.84
65	26	25.56	25.56	26.15	25.9	25.9	26.84	26.25	26.3	27.37	26.84	26.74	26	27.46	30.69	31.2
70	26.08	25.64	25.64	26.23	26.02	25.98	26.91	26.51	26.41	27.49	27.2	26.81	25.92	27.54	30.91	31.15
75	26.12	25.86	25.56	26.33	26.05	26.05	26.86	26.41	26.44	27.79	27.27	26.84	25.95	27.61	31.08	31.55
80	26.12	25.79	25.64	26.23	26.12	26.08	27.05	26.71	26.44	27.79	27.46	27.08	26.05	27.89	31.1	31.81
85	26.17	25.79	25.74	26.33	26.23	26.08	27.25	26.86	26.54	27.86	27.51	27.08	26	28.02	31.35	31.81
90	26.15	25.9	25.64	26.35	26.3	26.35	27.23	26.84	26.76	28.1	27.69	27.25	25.92	28	31.42	31.99
95	26.15	26.05	25.76	26.49	26.3	26.2	27.42	26.98	26.79	28.27	27.61	27.23	25.95	28.27	31.55	32.33
100	26.23	25.86	25.71	26.41	26.27	26.33	27.4	26.91	26.89	28.33	27.79	27.46	25.95	28.38	31.5	32.42
105	26.17	25.92	25.79	26.41	26.23	26.38	27.51	26.91	26.91	28.35	27.84	27.44	25.98	28.49	31.71	32.4
110	26.27	25.88	25.79	26.56	26.33	26.41	27.56	27	26.95	28.4	28.1	27.59	25.98	28.69	31.81	32.69
115	26.12	25.88	25.84	26.56	26.33	26.38	27.56	27.13	27.05	28.54	28.02	27.49	25.92	28.69	31.76	32.84
120	26.33	25.98	25.84	26.56	26.41	26.51	27.59	27.1	27.02	28.51	28.13	27.71	26.1	28.71	31.89	32.96

Table A5.10: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	26.33	26.02	25.88	26.74	26.49	26.39	27.66	27.27	27.13	28.79	28.2	27.71	26.08	28.79	32.13	33.06
130	26.33	26.08	25.81	26.56	26.61	26.46	27.74	27.2	27.17	28.91	28.25	27.86	26.1	29.05	32.04	33.16
135	26.35	26	25.71	26.56	26.41	26.51	27.94	27.25	27.05	28.84	28.35	27.98	25.98	29.08	32.06	33.2
140	26.27	26.12	25.79	26.71	26.51	26.61	27.81	27.35	27.23	28.86	28.48	28.2	26.2	29.05	32.25	33.33
145	26.3	25.92	25.92	26.64	26.54	26.69	27.95	27.37	27.17	28.91	28.42	28.08	26.1	29.1	32.35	33.42
150	26.3	25.9	25.95	26.84	26.59	26.49	27.95	27.46	27.37	28.96	28.49	28.1	26.25	29.4	32.33	33.58
155	26.3	25.98	25.88	26.74	26.64	26.54	27.91	27.46	27.33	29	28.61	28.35	26.1	29.45	32.55	33.62
160	26.39	26.15	25.86	26.92	26.54	26.64	28.02	27.59	27.49	29.08	28.76	28.33	26.12	29.51	32.66	33.65
165	26.35	25.9	25.76	26.91	26.66	26.66	28.13	27.44	27.42	29.15	28.61	28.2	25.86	29.66	32.5	33.89
170	26.49	26.1	25.86	26.84	26.74	26.69	28.15	27.56	27.59	29.42	28.99	28.15	25.84	29.54	32.63	33.91
175	26.39	25.92	25.84	26.84	26.74	26.79	28.2	27.66	27.66	29.4	28.91	28.3	26.05	29.89	32.64	34.14
180	26.38	25.92	25.92	26.79	26.74	26.74	28.2	27.81	27.66	29.4	28.96	28.48	26	29.81	32.86	34.16
185	26.41	25.84	25.88	26.84	26.69	26.74	28.1	27.66	27.59	29.27	29.08	28.56	25.98	29.94	32.81	34.22
190	26.46	25.88	25.74	26.89	26.64	26.79	28.2	27.81	27.69	29.54	29.02	28.74	25.69	29.94	32.84	34.33
195	26.35	25.95	25.9	26.92	26.89	26.74	28.08	27.74	27.64	29.42	29.13	28.54	25.92	29.99	32.71	34.42
200	26.25	25.9	25.86	26.86	26.66	26.81	28.27	27.69	27.69	29.74	29.13	28.69	26.02	30.08	32.94	34.38
205	26.23	25.98	25.84	26.81	26.71	26.84	28.2	27.71	27.74	29.71	29.17	28.84	26.02	30.33	32.86	34.38
210	26.27	25.92	25.84	26.84	26.71	26.84	28.2	27.81	27.76	29.64	29.15	28.76	25.86	30.2	32.84	34.58
215	26.3	25.9	25.81	26.86	26.79	26.74	28.33	27.84	27.94	29.86	29.23	28.91	25.69	30.33	32.86	34.33
220	26.3	25.95	25.86	26.95	26.69	26.81	28.27	27.79	27.84	29.64	29.23	28.79	25.84	30.23	32.94	34.55
225	26.33	26.08	25.79	26.89	26.84	26.92	28.45	27.91	27.95	29.79	29.35	28.64	25.76	30.35	32.84	34.72
230	26.23	25.84	25.88	26.89	26.89	26.79	28.35	27.81	27.84	29.84	29.38	28.89	25.92	30.33	32.89	34.7
235	26.44	25.92	25.84	26.89	26.84	26.84	28.48	27.94	27.81	29.96	29.45	29	25.9	30.61	32.96	34.72
240	26.35	25.95	25.86	26.81	26.66	26.76	28.48	27.94	27.94	29.84	29.38	29.08	25.92	30.48	32.99	34.79
245	26.23	25.98	25.88	26.98	26.74	26.89	28.38	27.81	27.91	29.89	29.5	29	25.95	30.5	33.16	34.7
250	26.33	25.98	25.81	26.95	26.86	26.95	28.3	27.91	27.91	29.89	29.4	29.17	25.86	30.64	32.99	34.81

Table A5.11: Experimental Data for Large Rashig Ring, $d_p = 3.87$ cm.
Run # 11: Re = 672.6 $Q_w = 19.8\ W/m^2$ $T_{amb} = 25.0\ ^oC$.
Time in (minutes), Temperature in (^oC) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
0	24.51	24.56	24.51	24.61	24.56	24.61	24.51	24.81	24.87	24.92	24.98	24.69	24.83	25.02	24.92	24.92
5	24.46	24.31	24.51	24.56	24.51	24.61	24.61	24.56	24.81	25	24.9	24.81	24.76	24.9	24.81	25.1
10	24.61	24.56	24.56	24.61	24.56	24.51	24.66	24.66	24.9	24.95	25	24.95	25	25.1	25.05	25.2
15	24.61	24.46	24.56	24.46	24.41	24.66	24.51	24.61	24.9	25	25.05	25	25.15	25	25.2	25.1
20	24.76	24.71	24.71	24.56	24.46	24.66	24.66	24.71	24.92	25.1	25.1	24.98	25.25	24.92	25.25	25.2
25	24.81	24.85	24.59	24.54	24.34	24.59	24.59	24.59	24.83	25.02	24.92	24.87	25.13	25.02	25.41	25.41
30	24.76	24.9	24.85	24.81	24.71	24.71	24.76	24.85	24.87	25.13	25.08	24.98	25.23	25.13	25.66	25.61
35	24.92	24.87	24.69	24.69	24.64	24.69	24.87	24.79	24.92	24.98	25.08	24.87	25.17	25.17	25.66	25.66
40	24.92	24.83	24.64	24.83	24.79	24.69	24.92	24.83	25.1	25.15	25.05	24.9	25.2	25.25	25.79	25.84
45	24.92	24.87	24.83	24.83	24.79	24.87	24.83	24.92	24.95	25.1	25.15	24.95	25.15	25.25	25.79	25.88
50	24.98	25.13	24.92	24.92	24.74	24.83	24.98	24.98	25.17	25.27	25.13	24.98	25.17	25.23	25.95	26
55	25.02	25.02	24.87	24.87	24.79	25.02	25.02	25.02	24.95	25.25	25.25	24.95	25.25	25.25	26.02	26.02
60	25.02	24.92	24.87	24.83	24.92	24.87	25.02	24.92	25.13	25.46	25.17	24.87	25.23	25.17	26.12	26.12
65	25.13	24.92	24.92	25.02	24.87	24.87	25.08	25.13	25.15	25.35	25.2	25.1	25.3	25.35	26.17	26.02
70	25.25	25.05	24.9	24.85	24.85	24.9	25.05	24.85	25.08	25.36	25.23	24.92	25.33	25.33	26.15	26.2
75	25.17	25.17	24.98	24.98	24.92	25.08	25.27	25.08	25.27	25.33	25.33	25.23	25.23	25.41	26.12	26.27
80	25.17	25.08	24.98	24.92	25.02	24.98	25.17	25.17	25.25	25.39	25.35	25.3	25.3	25.35	26.27	26.33
85	25.2	25.1	24.95	25	25	25.05	25.2	25.15	25.23	25.33	25.41	25.27	25.23	25.36	26.3	26.3
90	25.05	25.25	25	25	25.15	25.05	25.25	25.3	25.23	25.61	25.33	25.36	25.51	25.41	26.3	26.35
95	25.17	25.23	25.08	25.08	24.92	25.13	25.23	25.17	25.15	25.64	25.54	25.44	25.3	25.54	26.38	26.56
100	25.1	25.15	24.95	25	24.95	24.95	25.3	25.2	25.23	25.61	25.51	25.27	25.41	25.51	26.39	26.44
105	25.23	25.13	25.02	25.08	25.02	25.17	25.33	25.17	25.35	25.79	25.49	25.39	25.39	25.74	26.41	26.61
110	25.3	25.25	25	25.2	25	25.05	25.39	25.3	25.41	25.61	25.51	25.33	25.36	25.76	26.49	26.69
115	25.3	25.2	25.15	25.05	25	25.15	25.35	25.35	25.41	25.71	25.41	25.41	25.41	25.66	26.44	26.59
120	25.27	25.27	24.98	25.23	25.02	25.17	25.27	25.41	25.49	25.84	25.59	25.35	25.39	25.74	26.41	26.61

Table A5.11: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	25.35	25.35	25.05	25.2	25	25.2	25.3	25.3	25.49	25.69	25.74	25.44	25.39	25.79	26.59	26.59
130	25.17	25.23	25.02	25.17	24.98	25.27	25.66	25.46	25.39	25.69	25.64	25.64	25.59	25.74	26.56	26.71
135	25.36	25.27	25.17	25.23	25.23	25.23	25.36	25.46	25.33	25.76	25.61	25.61	25.56	25.9	26.49	26.79
140	25.25	25.35	25.15	25.15	25.1	25.3	25.49	25.44	25.46	25.71	25.71	25.51	25.61	25.71	26.56	26.76
145	25.49	25.3	25.05	25.2	25.25	25.25	25.54	25.49	25.51	25.71	25.71	25.36	25.56	25.86	26.59	26.79
150	25.46	25.33	25.27	25.27	25.23	25.33	25.46	25.56	25.39	25.98	25.69	25.44	25.49	25.88	26.61	26.91
155	25.59	25.35	25.3	25.35	25.2	25.2	25.64	25.54	25.46	25.95	25.76	25.61	25.56	25.86	26.64	26.84
160	25.41	25.36	25.17	25.23	25.23	25.41	25.46	25.56	25.46	25.81	25.71	25.76	25.51	25.95	26.74	26.79
165	25.44	25.44	25.3	25.25	25.2	25.35	25.69	25.49	25.71	25.81	25.9	25.61	25.46	25.95	26.69	26.84
170	25.41	25.36	25.27	25.33	25.13	25.46	25.56	25.46	25.64	25.92	25.84	25.64	25.59	26.02	26.61	26.91
175	25.44	25.39	25.3	25.3	25.25	25.25	25.54	25.39	25.56	26.05	25.76	25.51	25.56	25.9	26.69	26.89
180	25.51	25.41	25.33	25.27	25.33	25.46	25.61	25.61	25.66	25.95	25.86	25.71	25.41	26.05	26.74	26.92
185	25.36	25.41	25.35	25.36	25.3	25.35	25.61	25.61	25.74	25.92	25.84	25.59	25.49	25.98	26.79	26.92
190	25.44	25.35	25.3	25.35	25.3	25.3	25.54	25.59	25.51	26	25.86	25.51	25.51	26	26.64	26.86
195	25.51	25.46	25.23	25.41	25.33	25.27	25.56	25.61	25.59	25.88	25.79	25.92	25.79	26.12	26.81	27.05
200	25.46	25.46	25.27	25.36	25.27	25.36	25.76	25.66	25.51	25.86	25.95	25.81	25.66	26	26.79	26.89
205	25.61	25.46	25.33	25.36	25.33	25.41	25.71	25.61	25.74	26.02	25.98	25.88	25.64	26.17	26.76	27
210	25.54	25.44	25.35	25.49	25.35	25.49	25.59	25.69	25.71	25.95	25.86	25.71	25.71	26.05	26.69	27.02
215	25.59	25.49	25.44	25.44	25.35	25.44	25.74	25.69	25.79	26.08	25.88	25.74	25.69	26.27	26.81	27
220	25.51	25.39	25.44	25.49	25.44	25.39	25.56	25.71	25.69	26.02	25.88	25.64	25.74	26.02	26.81	27.05
225	25.64	25.54	25.44	25.39	25.39	25.44	25.69	25.79	25.66	26.1	26	25.71	25.71	26.2	26.69	27.13

Table A5.12: Experimental Data for Large Rashig Ring, $d_p = 3.87$ cm.
Run # 12: Re = 447.4 $Q_w = 19.8$ W/m^2 $T_{amb} = 24.5$ °C.
Time in (minutes), Temperature in (°C) and (x,y) in cm.

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	$T_w 1$	$T_w 2$
0	24.2	24.25	24.05	24.1	23.95	24.3	24.15	24.15	24.61	24.46	24.46	24.36	24.08	24.46	24.56	24.31
5	24.15	24	23.9	24	23.85	24	24.1	24.1	24.31	24.31	24.27	24.41	24.27	24.31	24.56	24.46
10	24.23	24.23	24.17	24.02	23.98	24.02	24.13	24.13	24.41	24.46	24.46	24.23	24.27	24.56	24.61	24.71
15	24.27	24.08	23.88	23.88	23.92	24.02	24.02	24.13	24.41	24.36	24.41	24.41	24.17	24.31	24.71	24.76
20	24.13	24.17	23.98	24.08	24.08	24.13	24.13	24.27	24.44	24.49	24.54	24.44	24.34	24.49	24.79	24.87
25	24.15	24.1	23.95	23.8	23.9	23.9	24.1	24.1	24.44	24.44	24.34	24.34	24.3	24.59	24.98	25.08
30	24.13	24.02	24.02	24.08	23.98	24.17	24.23	24.31	24.49	24.49	24.59	24.3	24.15	24.44	25.02	25.27
35	24.27	23.98	23.92	23.9	23.92	24.02	24.23	24.27	24.51	24.66	24.51	24.41	24.27	24.61	25.27	25.36
40	24.2	24.2	24.1	24	24.05	24.2	24.3	24.3	24.41	24.56	24.61	24.41	24.36	24.66	25.3	25.44
45	24.13	24.13	24.02	23.92	24.02	24.08	24.27	24.27	24.41	24.66	24.56	24.56	24.51	24.61	25.3	25.44
50	24.23	24.17	24.13	24.17	24.13	24.23	24.36	24.41	24.44	24.69	24.64	24.49	24.34	24.79	25.41	25.41
55	24.2	24.15	24.05	24.15	24.05	24.25	24.34	24.3	24.61	24.76	24.66	24.46	24.31	24.85	25.44	25.69
60	24.34	24.3	24.15	24.25	24.05	24.25	24.3	24.59	24.76	24.66	24.81	24.51	24.46	24.85	25.54	25.79
65	24.2	24.25	24	24.2	24.15	24.2	24.39	24.49	24.64	24.83	24.69	24.59	24.64	24.74	25.46	25.76
70	24.39	24.31	24.08	24.27	24.23	24.31	24.44	24.39	24.56	24.81	24.66	24.41	24.56	24.85	25.59	25.84
75	24.44	24.3	24.15	24.25	24.15	24.15	24.44	24.34	24.64	24.83	24.79	24.54	24.59	24.83	25.71	26
80	24.41	24.31	24.27	24.23	24.23	24.27	24.51	24.51	24.59	24.92	24.79	24.74	24.64	24.83	25.66	25.95
85	24.36	24.31	24.13	24.27	24.31	24.31	24.41	24.46	24.71	24.95	24.81	24.51	24.66	25.05	25.88	25.98
90	24.39	24.34	24.1	24.39	24.39	24.3	24.59	24.54	24.69	24.98	25.02	24.83	24.69	25.08	25.98	26.02
95	24.39	24.25	24.2	24.34	24.25	24.3	24.64	24.64	24.74	25.13	24.79	24.74	24.69	24.98	25.88	26.02
100	24.49	24.49	24.3	24.49	24.39	24.39	24.64	24.59	24.64	25.13	25.02	24.83	24.64	25.02	26	26.15
105	24.49	24.39	24.3	24.39	24.3	24.3	24.59	24.54	24.66	25.05	25	24.81	24.71	25.15	26.02	26.23
110	24.56	24.46	24.31	24.36	24.46	24.46	24.81	24.46	24.74	24.87	24.87	24.87	24.74	25.08	26.1	26.2
115	24.44	24.59	24.34	24.44	24.39	24.39	24.74	24.59	24.85	25.15	25.05	24.81	24.76	25.2	26.08	26.33
120	24.66	24.46	24.36	24.56	24.31	24.46	24.79	24.71	24.9	25.1	24.9	24.76	24.61	25.25	26.02	26.44

Table A5.12: (Continued)

Time	T(30,8)	T(30,5)	T(30,2)	T(63,8)	T(63,5)	T(63,2)	T(96,8)	T(96,5)	T(96,2)	T(129,8)	T(129,5)	T(129,2)	T_{in}	T_{out}	T_w 1	T_w 2
125	24.49	24.39	24.27	24.54	24.44	24.44	24.79	24.64	24.83	25.27	25.02	24.92	24.64	25.27	26.05	26.35
130	24.61	24.41	24.46	24.66	24.61	24.46	24.76	24.76	24.74	25.17	25.23	24.87	24.79	25.27	26.1	26.35
135	24.64	24.49	24.39	24.54	24.44	24.44	24.83	24.79	24.83	25.23	25.17	25.02	24.69	25.23	26.23	26.46
140	24.74	24.49	24.39	24.59	24.49	24.54	24.95	24.79	24.87	25.23	25.23	25.02	24.79	25.33	26.23	26.46
145	24.69	24.39	24.44	24.54	24.49	24.59	24.92	24.74	24.76	25.2	25.05	25	24.71	25.49	26.23	26.46
150	24.66	24.51	24.41	24.56	24.61	24.56	24.81	24.81	24.87	25.23	25.13	24.98	24.79	25.51	26.25	26.39
155	24.71	24.56	24.39	24.56	24.51	24.66	25	24.85	24.92	25.51	25.17	25.02	24.64	25.41	26.15	26.54
160	24.69	24.44	24.41	24.49	24.44	24.54	24.83	24.87	25	25.25	25.25	25.15	24.76	25.39	26.27	26.56
165	24.59	24.54	24.39	24.59	24.44	24.59	24.87	24.74	24.98	25.33	25.27	25.13	24.83	25.41	26.3	26.49
170	24.64	24.54	24.41	24.64	24.54	24.69	24.83	24.83	24.9	25.39	25.2	25	24.71	25.39	26.33	26.61
175	24.69	24.54	24.34	24.54	24.79	24.69	24.92	24.87	25	25.39	25.25	25.15	24.61	25.35	26.33	26.46
180	24.66	24.56	24.46	24.61	24.66	24.51	24.98	24.87	24.85	25.25	25.1	25.05	24.66	25.59	26.25	26.64
185	24.66	24.51	24.36	24.66	24.56	24.66	24.98	24.81	24.85	25.39	25.3	25.15	24.71	25.44	26.39	26.49
190	24.59	24.69	24.54	24.54	24.64	24.49	24.81	24.95	25.02	25.27	25.23	25.23	24.64	25.61	26.25	26.56

APPENDIX B
COMPUTER PROGRAM FOR SOLVING THE HEAT EQUATION

```
!CC ************************************************************************
!CC ****                        CHE 610 THESIS
!CC ****
!CC ****      TRANSIENT CONVECTION HEAT TRANSFER IN A PACKED
!CC ****      RECTANGULAR DUCT WITH ASYMMETRIC HEATING.
!CC ****
!CC ****      A PROGRAM TO CALCULATE THE RADIAL AND AXIAL
!CC ****      AIR TEMPERATURES AT DIFFERENT LOCATION OF A PACKED
!CC ****      DUCT USING THE METHOD OF ORTHOGONAL COLLOCATION.
!CC ****
!CC ****      PREPARED BY : MOHAMMED SHUBBER AL-QALLAF.
!CC ****      ID # 857421
!CC ****      TERM : 981
!CC ***********************************************************************
!CC ***********************************************************************
!C
!C                            NOMENCLATURE
!C
!C     A, B, CN,    Parameters in the Zehner & Schlunder radial thermal
!C     M, Ni        conductivity equation.
!C     ALPHAX       Aspect ratio in the axial direction.
!C     ALPHAR       Aspect ratio in the radial direction.
!C     AXIAL        Axial dispersion.
!C     AX,BX        Legendre matrix parameters for the first and second derivative in
!C                  the axial direction.
!C     AY,BY        Legendre matrix parameters for the first and second derivative in
!C                  the radial direction.
!C     BIS          Solid/wall Biot number.
!C     C            Heat capacity ratio.          (C=E*RHOF/(1-E)/RHOS/CS)
!C     CF           Specific heat of the fluid.                  (J/Kg/°C)
!C     CS           Specific heat of the solid.                  (J/Kg/°C)
!C     DE           Equivalent diameter of the duct.                  (m)
!C     DELT         Time increment.
!C     DP           Equivalent diameter of the particle.              (m)
!C     DX,DY        Dimensionless axial and radial roots of the polynomials.
!C     E            Bed void fraction ( Porosity ).
!C     F1           Constant in the radial dispersion term of the heat equation.
!C     F2           Constant in the axial dispersion term of the heat equation.
!C     F3           Constant on the convection term of the heat equation.
!C     F4           Second boundary condition at X = 1.0.
!C     G            Mass flux.                                 (Kg/m^2/sec)
```

```
!C    H          Height of the duct.                                          (m)
!C    KDYR       Dynamic thermal conductivity in the radial direction.  (Watt/m/K)
!C    KEA        Thermal conductivity in the axial direction.           (Watt/m/K)
!C    KER        Thermal conductivity in the radial direction.          (Watt/m/K)
!C    KG         Thermal conductivity of the fluid.                     (Watt/m/K)
!C    KS         Thermal conductivity of the solid.                     (Watt/m/K)
!C    KSTR       Stagnant thermal conductivity in the radial direction. (Watt/m/K)
!C    L          Length of the duct.                                          (m)
!C    MCF        Mass velocity times fluid specific heat.                (Watt/°C)
!C    MUE        Viscosity of the fluid.                                (Kg/m/sec)
!C    M,N        Number of roots in the radial and axial
!C               directions respectively.                        (N+2 x M+2 grid)
!C    NB         Number of Nodes in the boundaries.
!C    NEQ        Number of interior nodes.
!C    NS         Interphase heat transfer group.
!C    NUFS       Fluid/Solid Nusselt number.
!C    Q          Fourth boundary condition at  Y = 1.0.
!C    QW         Heat flux.                                              (Watt/m2)
!C    PEA        Peclet number in the axial direction.        (PEA=G*CF*DP/KEA)
!C    PEAF       Limiting value of Peclet number as Re goes to infinity.
!C    PER        Peclet number in the radial direction.       (PER=G*CF*DP/KER)
!C    RADIAL     Radial dispersion.
!C    RE         Reynolds number.                                 (RE= G*DP/MUE.)
!C    RHOF       Density of the fluid.                                    (Kg/m3)
!C    RHOS       Density of the solid.                                    (Kg/m3)
!C    S( )       Dimensionless temperature vector for nodes at the boundaries.
!C    T          Dimensionless time TAU.
!C    TEM        Dimensional temperature.                                   (°C)
!C    TIME       Dimensional Time.                                     (Minutes)
!C    TO         Inlet temperature.                                         (°C)
!C    U          Superficial velocity inside the duct.                   (m/sec)
!C    W          Width of the duct.                                          (m)
!C    X,Y        Dimensional axial and radial roots of the polynomials.      (m)
!C    Z( )       Dimensionless temperature vector for interior nodes.
!C    ZPRIME     Accumulation term in the heat equation.                 (dZ/dT)
!C
!CC *********************************************************************
!CC *********************************************************************
```

!CC ******** **Main Program** *****

```
USE MSIMSL
INTEGER NEQ, MXPARM,IDO,NOUT
PARAMETER (NEQ=162,MXPARM=50,NB=58)
DOUBLE PRECISION :: AX(20,20),BX(20,20),AY(11,11),BY(11,11)
```

```
      DOUBLE PRECISION:: FCN, FLOAT ,PARAM(MXPARM) ,T,TEND ,TOL, Z(NEQ), T1(NB),
                         T2(NEQ) ,QW ,Q ,DX(20) ,X(20) ,DY(11) ,Y(11), TEMAVG(12),
                         RADIAL(8) , AXIAL(8), DZDY(8), DZDX(8)
      DOUBLE PRECISION:: H,W, L, DP, DE, U, CF, RHOF, RHOS, MUE, E, KG, KS, KEA,
                         KSTR, KDYR, KER, TIME, PEA, PER, C, CS, F1, F2, F3, F4, MCF,
                         A, B, M, CN, Ni, BIS, NUFS, PR, PEAF, NS, ALPHAX, ALPHAR
      INTRINSIC FLOAT
      EXTERNAL FCN
      COMMON/AREA/S(NB),F1,F2,F3,F4,AX,BX,BY
      OPEN (UNIT=5,FILE='CHE610.OUT',STATUS='UNKNOWN')
      CALL LEGANDMATRIX (AY, BY, AX, BX, DY, DX)
      CALL UMACH (2,NOUT)
!C    SET THE INITIAL CONDITIONS
      T=0.0
      DO I = 1,NEQ
      Z(I)=1.0
      ENDDO
      DO I = 1,NB
      S(I)=1.0
      ENDDO
!C    SET THE ERROR TOLERANCE
      TOL = 1.0E-4
      CALL SSET (MXPARM,0.0,PARAM,1)
!C    SELECT ABSOLUTE ERROR CONTROL
      PARAM(10) = 1.0
      PARAM(4) = 450000
      H  = 0.1
      L  = 1.6
      W = 0.4
      DP = 0.0387
      DE = 0.2169
      TO = 24.0
      MCF = 20.5
      U = 0.432
      QW = 179.2
      RHOF = 1.1769
      RHOS = 25.0
      MUE = 1.8464E-5
      CF = 1.0063E3
      CS = 1250
      E = 0.403
      PR = 0.7
      KG =  2.624E-2
      KS = 0.037

!C    RE = G*DP/MUE
      G= MCF/CF/H/W
      RE = G*DP/MUE
!C    CALCULATION OF THE RADIAL THERMAL CONDUCTIVITY BASED
      ON ZEHNER & SCHLUNDER , 1973.
!C    FOR SPHERES CN = 1.25
!C    FOR RASHING RINGS CN = 2.5
      CN = 1.25
      B  = CN * ((1-E)/E)**1.1
      M  = B* KG/KS
```

```
      A  = 2/(1-M)*((B-M)/(1-M)**2*(LOG(1/M))-(B+1)/2-(B-1)/(1-M))
      KSTR= KG*(0.67*E+A*SQRT(1-E))
!C    Ni =De/Dp = 5.636
      Ni =DE/DP
      KDYR = G*DP*CF/8/(2-(1-2/Ni)**2)
      KER = KSTR + KDYR
      ALPHAX = DP/L
      ALPHAR = DP/H
!C    CALCULATION OF THE AXIAL THERMAL CONDUCTIVITY USING THE
      RELATION DEVELOPED BY DIXON 1979.
      BIS = 2.12*Ni/2.
      NUFS = 0.255/E*PR**(1./3.)*RE**(2./3.)
      NS = 1.5*(1.-E)*Ni**2/(KSTR/KG)/(1./NUFS+0.1/KS/KG)
      PEAF = 0.5
      PEA = 1./(1./PEAF+(KSTR/KG)/RE/PR/(1.+1./NS*8.*BIS/(BIS+4.))**2)
      KEA = G*CF*DP/PEA
      C = E*RHOF*CF/(1-E)/RHOS/CS
      PER = G*CF*DP/KER
      F1= ALPHAR**2/PER/(1.+C)
      F2= ALPHAX**2/PEA/(1.+C)
      F3= ALPHAX/(1.+C)
      F4= QW*W*L/MCF/TO
      Q = QW*H/TO/KER
      DELT=60.0*G*CF/DP/(1-E)/RHOS/CS
      ICOUNT = 0
      WRITE (5,888) 'DP =',DP
      WRITE (5,888) 'U =',U
      WRITE (5,888) 'MASS FLUX =',G
      WRITE (5,888) 'HEAT FLUX =',QW
      WRITE (5,888) 'Re =',RE
      WRITE (5,888) 'Kstr =',KSTR
      WRITE (5,888) 'Kdyr =',KDYR
      WRITE (5,888) 'Kea =',KEA
      WRITE (5,888) 'Ker =',KER
      WRITE (5,888) 'Pea =',PEA
      WRITE (5,888) 'Per =',PER
      WRITE (5,888) 'Aspect Ratio in X-direction =',ALPHAX
      WRITE (5,888) 'Aspect Ratio in R-direction =',ALPHAR
      WRITE (5,888) 'To =',TO
      WRITE (5,888) 'Heat Capacity Ratio =',C
      WRITE (5,888) 'Q =',Q
      WRITE (5,888) 'F1 =',F1
      WRITE (5,888) 'F2 =',F2
      WRITE (5,888) 'F3 =',F3
      WRITE (5,888) 'F4 =',F4
      WRITE (5,888) 'POROSITY,E =',E
      WRITE (5,888) 'Deltatau =',DELT
      WRITE (5,*)
!C    LEGENDRE COLLOCATION POINTS
!C    M=  9
      DO I =1,11
      Y(I) = DY(I)* H
      WRITE(5,777) 'Y(',I,') = ',Y(I)
      WRITE(5,*)
      ENDDO
```

```
!C      N=18
        DO I = 1,20
        X(I) = DX(I)* L
        WRITE(5,777) 'X(',I,')=',X(I)
        WRITE(5,*)
        ENDDO
        WRITE(5,15)
        WRITE (5,*)
15      FORMAT ('  TIME  T(30,8) T(30,5) T(30,2) T(63,8) T(63,5) T(63,2) T(96,8) T(96,5) T(96,2)
                T(129,8) T(129,5) T(129,2) TIME RADIAL(1) AXIAL(1) RADIAL(3) AXIAL(3)
                RADIAL(5) AXIAL(5) RADIAL(7) AXIAL(7) TIME RADIAL(2) AXIAL(2)
                RADIAL(4) AXIAL(4) RADIAL(6) AXIAL(6) RADIAL(8) AXIAL(8) TIME
                dZ/dY(1) dZ/dX(1) dZ/dY(3) dZ/dX(3) dZ/dY(5) dZ/dX(5) dZ/dY(7) dZ/dX(7)
                TIME dZ/dY(2) dZ/dX(2) dZ/dY(4) dZ/dX(4) dZ/dY(6) dZ/dX(6) dZ/dY(8)
                dZ/dX(8)')
        DO I =1,NEQ
        T2(I)=Z(I)*TO
        ENDDO
        CALL TEMPAVG(NEQ,TEMAVG,T2)
        WRITE (5,600) TIME, TEMAVG(1), TEMAVG(2), TEMAVG(3), TEMAVG(4), TEMAVG(5),
                TEMAVG(6),TEMAVG(7), TEMAVG(8), TEMAVG(9), TEMAVG(10),
                TEMAVG(11), TEMAVG(12), TIME, RADIAL(1), AXIAL(1), RADIAL(3),
                AXIAL(3), RADIAL(5), AXIAL(5), RADIAL(7), AXIAL(7), TIME,
                RADIAL(2), AXIAL(2), RADIAL(4), AXIAL(4), RADIAL(6), AXIAL(6),
                RADIAL(8), AXIAL(8), TIME, DZDY(1), DZDX(1), DZDY(3), DZDX(3),
                DZDY(5), DZDX(5), DZDY(7), DZDX(7), TIME, DZDY(2), DZDX(2),
                DZDY(4), DZDX(4), DZDY(6), DZDX(6), DZDY(8), DZDX(8)
600     FORMAT (1X, F6.1, 2X, 12F9.4, 2X, F6.1, 8F10.6, 2X,F6.1, 8F10.6, 2X,F6.1, 8F10.6, 2X, F6.1,
            8F10.6)
777     FORMAT (6X, A, I2, A,1X, F5.2)
888     FORMAT (6X, A, 2X, F10.5)
        IDO=1
        DO 10 FSTEP = 0, 20000, DELT
        TEND = FSTEP
        CALL DIVPRK (IDO, NEQ, FCN, T, TEND, TOL, PARAM, Z)
!C      EQUATIONS TO CALCULATE THE TEMPERATURE AT THE
        BOUNDARY CONDITIONS OF THE DUCT.
        DO I =1,NB
        T1(I)=S(I)*TO
        ENDDO
        DO I =1,NEQ
        T2(I)=Z(I)*TO
        ENDDO
        TIME = T*DP*(1-E)*RHOS*CS/G/CF/60.
        CALL AXIALDISPER (RADIAL, AXIAL, DZDX, DZDY, NEQ, Z, S, NB, F1,F2, AX,
                AY, BX, BY)
        IF (ICOUNT.LT.5) GOTO 50
        CALL TEMPAVG (NEQ, TEMAVG, T2)
        WRITE (5,600) TIME, TEMAVG(1), TEMAVG(2), TEMAVG(3), TEMAVG(4), TEMAVG(5),
                TEMAVG(6),TEMAVG(7), TEMAVG(8), TEMAVG(9), TEMAVG(10),
                TEMAVG(11), TEMAVG(12), TIME, RADIAL(1), AXIAL(1), RADIAL(3),
                AXIAL(3), RADIAL(5), AXIAL(5), RADIAL(7), AXIAL(7), TIME,
                RADIAL(2), AXIAL(2), RADIAL(4), AXIAL(4), RADIAL(6), AXIAL(6),
                RADIAL(8), AXIAL(8), TIME, DZDY(1), DZDX(1), DZDY(3), DZDX(3),
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```
                    DZDY(5), DZDX(5), DZDY(7), DZDX(7), TIME, DZDY(2), DZDX(2),
                    DZDY(4), DZDX(4), DZDY(6), DZDX(6), DZDY(8), DZDX(8)
      ICOUNT=0
50    ICOUNT=1+ICOUNT

!C    POLYNOMIAL EQUATIONS FOR NODES AT THE BOUNDARIES.

      DO I = 1,11
      S(I) = 1.0
      ENDDO
      S(12) = -(SUM(AY(1,2:10)*Z(1:9))+AY(1,11)*S(13))/AY(1,1)
      S(13) = (Q-(AY(11,1)*S(12)+SUM(AY(11,2:10)*Z(1:9))))/AY(11,11)
      S(14) = -(SUM(AY(1,2:10)*Z(10:18))+AY(1,11)*S(15))/AY(1,1)
      S(15) = (Q-(AY(11,1)*S(14)+SUM(AY(11,2:10)*Z(10:18))))/AY(11,11)
      S(16) = -(SUM(AY(1,2:10)*Z(19:27))+AY(1,11)*S(17))/AY(1,1)
      S(17) = (Q-(AY(11,1)*S(16)+SUM(AY(11,2:10)*Z(19:27))))/AY(11,11)
      S(18) = -(SUM(AY(1,2:10)*Z(28:36))+AY(1,11)*S(19))/AY(1,1)
      S(19) = (Q-(AY(11,1)*S(18)+SUM(AY(11,2:10)*Z(28:36))))/AY(11,11)
      S(20) = -(SUM(AY(1,2:10)*Z(37:45))+AY(1,11)*S(21))/AY(1,1)
      S(21) = (Q-(AY(11,1)*S(20)+SUM(AY(11,2:10)*Z(37:45))))/AY(11,11)
      S(22) = -(SUM(AY(1,2:10)*Z(46:54))+AY(1,11)*S(23))/AY(1,1)
      S(23) = (Q-(AY(11,1)*S(22)+SUM(AY(11,2:10)*Z(46:54))))/AY(11,11)
      S(24) = -(SUM(AY(1,2:10)*Z(55:63))+AY(1,11)*S(25))/AY(1,1)
      S(25) = (Q-(AY(11,1)*S(24)+SUM(AY(11,2:10)*Z(55:63))))/AY(11,11)
      S(26) =-(SUM(AY(1,2:10)*Z(64:72))+AY(1,11)*S(27))/AY(1,1)
      S(27) = (Q-(AY(11,1)*S(26)+SUM(AY(11,2:10)*Z(64:72))))/AY(11,11)
      S(28) = -(SUM(AY(1,2:10)*Z(73:81))+AY(1,11)*S(29))/AY(1,1)
      S(29) = (Q-(AY(11,1)*S(28)+SUM(AY(11,2:10)*Z(73:81))))/AY(11,11)
      S(30) = -(SUM(AY(1,2:10)*Z(82:90))+AY(1,11)*S(31))/AY(1,1)
      S(31) = (Q-(AY(11,1)*S(30)+SUM(AY(11,2:10)*Z(82:90))))/AY(11,11)
      S(32) = -(SUM(AY(1,2:10)*Z(91:99))+AY(1,11)*S(33))/AY(1,1)
      S(33) = (Q-(AY(11,1)*S(32)+SUM(AY(11,2:10)*Z(91:99))))/AY(11,11)
      S(34) = -(SUM(AY(1,2:10)*Z(100:108))+AY(1,11)*S(35))/AY(1,1)
      S(35) = (Q-(AY(11,1)*S(34)+SUM(AY(11,2:10)*Z(100:108))))/AY(11,11)
      S(36) = -(SUM(AY(1,2:10)*Z(109:117))+AY(1,11)*S(37))/AY(1,1)
      S(37) = (Q-(AY(11,1)*S(36)+SUM(AY(11,2:10)*Z(109:117))))/AY(11,11)
      S(38) = -(SUM(AY(1,2:10)*Z(118:126))+AY(1,11)*S(39))/AY(1,1)
      S(39) = (Q-(AY(11,1)*S(38)+SUM(AY(11,2:10)*Z(118:126))))/AY(11,11)
      S(40) = -(SUM(AY(1,2:10)*Z(127:135))+AY(1,11)*S(41))/AY(1,1)
      S(41) = (Q-(AY(11,1)*S(40)+SUM(AY(11,2:10)*Z(127:135))))/AY(11,11)
      S(42) = -(SUM(AY(1,2:10)*Z(136:144))+AY(1,11)*S(43))/AY(1,1)
      S(43) = (Q-(AY(11,1)*S(42)+SUM(AY(11,2:10)*Z(136:144))))/AY(11,11)
      S(44) = -(SUM(AY(1,2:10)*Z(145:153))+AY(1,11)*S(45))/AY(1,1)
      S(45) = (Q-(AY(11,1)*S(44)+SUM(AY(11,2:10)*Z(145:153))))/AY(11,11)
      S(46) = -(SUM(AY(1,2:10)*Z(154:162))+AY(1,11)*S(47))/AY(1,1)
      S(47) = (Q-(AY(11,1)*S(46)+SUM(AY(11,2:10)*Z(154:162))))/AY(11,11)
      S(48) = (F4-(AX(20,1)*S(1)+AX(20,2)*S(12)+AX(20,3)*S(14)+AX(20,4)*S(16) +AX(20,5)*
              S(18)+AX(20,6)*S(20)+AX(20,7)*S(22)+AX(20,8)*S(24)+AX(20,9)*S(26)+AX(20,10)
              *S(28)+AX(20,11)*S(30)+AX(20,12)*S(32)+AX(20,13)*S(34)+AX(20,14)*S(36)+AX
              (20,15)*S(38)+AX(20,16) *S(40)+AX(20,17)*S(42)+AX(20,18)*S(44)+AX(20,19) *
              S(46)))/ AX(20,20)
      S(49)=(F4-(AX(20,1)*S(2)+AX(20,2)*Z(1)+AX(20,3)*Z(10)+AX(20,4)*Z(19)+AX(20,5) *Z(28)
              +AX(20,6)*Z(37)+AX(20,7)*Z(46)+AX(20,8)*Z(55)+ AX(20,9)*Z(64)+AX (20,10)
              *Z(73)+AX(20,11)*Z(82)+AX(20,12)* Z(91)+AX(20,13)*Z(100)+AX(20,14)
```

```
     *Z(109)+AX(20,15)*Z(118)+ AX(20,16)*Z(127)+AX(20,17)*Z(136)+AX(20,18)
     *Z(145)+AX(20,19)* Z(154)))/AX(20,20)
   S(50) = (F4-(AX(20,1)*S(3)+AX(20,2)*Z(2)+AX(20,3)*Z(11)+AX(20,4)* Z(20) +AX(20,5)
       *Z(29)+AX(20,6)*Z(38)+AX(20,7)*Z(47)+AX(20,8)* Z(56) +AX(20,9)*Z(65)+
       AX(20,10)*Z(74)+AX(20,11)*Z(83)+AX(20,12) * Z(92)+AX(20,13)*Z(101)+ AX
       (20,14) *Z(110)+AX(20,15)*Z(119)+ AX(20,16)*Z(128)+AX(20,17)*Z(137)+AX
       (20,18)*Z(146)+AX(20,19)*Z(155)))/AX(20,20)
   S(51) = (F4-(AX(20,1)*S(4)+AX(20,2)*Z(3)+AX(20,3)*Z(12)+AX(20,4)*Z(21) +AX(20,5)*
       Z(30)+AX(20,6)*Z(39)+AX(20,7)*Z(48)+AX(20,8)*Z(57) +AX(20,9)*Z(66)+ AX
       (20,10)*Z(75)+AX(20,11)*Z(84)+AX(20,12)* Z(93)+AX(20,13)*Z(102)+AX(20,14)
       *Z(111)+AX(20,15)*Z(120)+ AX(20,16)*Z(129)+AX(20,17)*Z(138)+AX(20,18)
       *Z(147)+AX(20,19)*Z(156)))/AX(20,20)
   S(52) = (F4-(AX(20,1)*S(5)+AX(20,2)*Z(4)+AX(20,3)*Z(13)+AX(20,4)*Z(22) +AX(20,5)*
       Z(31) +AX(20,6)*Z(40)+AX(20,7)*Z(49)+AX(20,8)*Z(58)+AX(20,9)*Z(67)+AX
       (20,10)*Z(76)+AX(20,11)*Z(85)+AX(20,12)* Z(94)+AX(20,13)*Z(103)+AX(20,14)
       *Z(112)+AX(20,15)*Z(121)+ AX(20,16)*Z(130)+AX(20,17)*Z(139)+AX(20,18)
       *Z(148)+AX(20,19)*Z(157)))/AX(20,20)
   S(53) = (F4-(AX(20,1)*S(6)+AX(20,2)*Z(5)+AX(20,3)*Z(14)+AX(20,4)*Z(23) +AX(20,5)
       *Z(32)+AX(20,6)*Z(41)+AX(20,7)*Z(50)+AX(20,8)*Z(59)+AX(20,9)*Z(68)+AX(20,
       10)*Z(77)+AX(20,11)*Z(86)+AX(20,12)* Z(95)+AX(20,13)*Z(104)+AX(20,14)
       *Z(113)+AX(20,15)*Z(122)+ AX(20,16)*Z(131)+AX(20,17)*Z(140)+AX(20,18)
       *Z(149)+AX(20,19)*Z(158)))/AX(20,20)
   S(54) = (F4-(AX(20,1)*S(7)+AX(20,2)*Z(6)+AX(20,3)*Z(15)+AX(20,4)*Z(24) +AX(20,5)*
       Z(33)+AX(20,6)*Z(42)+AX(20,7)*Z(51)+AX(20,8)*Z(60)+AX(20,9)*Z(69)+AX
       (20,10)*Z(78)+AX(20,11)*Z(87)+AX(20,12)* Z(96 )+AX(20,13)*Z(105)+AX(20,14)*
       Z(114) +AX(20,15)*Z(123)+ AX(20,16)*Z(132)+AX(20,17)*Z(141)+AX(20,18)
       *Z(150)+AX (20,19) *Z(159)))/AX(20,20)
   S(55) = (F4-(AX(20,1)*S(8)+AX(20,2)*Z(7)+AX(20,3)*Z(16)+AX(20,4)*Z(25) +AX(20,5)*
       Z(34)+AX(20,6)*Z(43)+AX(20,7)*Z(52)+AX(20,8)*Z(61)+AX(20,9)*Z(70)+AX
       (20,10)*Z(79)+AX(20,11)*Z(88)+AX(20,12)* Z(97)+AX(20,13)*Z(106)+AX(20,14)
       *Z(115) +AX(20,15)* Z(124)+ AX(20,16)*Z(133)+AX(20,17)*Z(142)+AX(20,18)*
       Z(151)+ AX(20,19)*Z(160)))/AX(20,20)
   S(56) = (F4-(AX(20,1)*S(9)+AX(20,2)*Z(8)+AX(20,3)*Z(17)+AX(20,4)*Z(26) +AX(20,5)*
       Z(35)+AX(20,6)*Z(44)+AX(20,7)*Z(53)+AX(20,8)*Z(62)+AX(20,9)*Z(71)+ AX
       (20,10) *Z(80)+AX(20,11)*Z(89)+AX(20,12)* Z(98)+AX(20,13)*Z(107)+AX(20,14)
       *Z(116)+AX(20,15)*Z(125)+ AX(20,16)*Z(134)+AX(20,17)*Z(143)+AX(20,18)
       *Z(152)+AX(20,19)*Z(161)))/AX(20,20)
   S(57) = (F4-(AX(20,1)*S(10)+AX(20,2)*Z(9)+AX(20,3)*Z(18)+AX(20,4)*Z(27) +AX(20,5)
       *Z(36)+AX(20,6)*Z(45)+AX(20,7)*Z(54)+AX(20,8)*Z(63)+AX(20,9)*Z(72)+AX
       (20,10)*Z(81)+AX(20,11)*Z(90)+AX(20,12)* Z(99)+AX(20,13)*Z(108)+AX(20,14)*
       Z(117) +AX(20,15)*Z(126)+ AX(20,16)*Z(135)+AX(20,17)*Z(144)+AX(20,18)
       *Z(153)+AX(20,19)*Z(162)))/AX(20,20)
   S(58) = (F4-(AX(20,1)*S(11)+AX(20,2)*S(13)+AX(20,3)*S(15) +AX(20,4)* S(17)+AX(20,5)*
       S(19)+AX(20,6)*S(21)+AX(20,7)*S(23)+AX(20,8)* S(25)+AX(20,9)*S(27)+ AX
       (20,10) *S(29)+AX(20,11)*S(31)+AX(20,12)*S(33)+AX(20,13)*S(35)+ AX(20,14)*
       S(37)+AX(20,15)*S(39)+AX (20,16)*S(41)+AX(20,17)*S(43)+AX(20,18)*
       S(45)+AX(20,19)*S(47)))/AX(20,20)

10 CONTINUE
!C FINAL CALL TO RELEASE THE WORKSPACE
   IDO=3
   CALL DIVPRK (IDO, NEQ, FCN, T, TEND, TOL, PARAM, Z)
   END
!C SUBROUTINE FUNTCTON TO SOLVE THE POLYNOMIALS OF THE
!C INTERIOR NODES USING THE IMSL SUBROUTINE DIVPRK.
```

```
SUBROUTINE FCN(NEQ,T,Z,ZPRIME)
PARAMETER(NB=58)
INTEGER NEQ
DOUBLE PRECISION :: AX(20,20),BX(20,20),BY(11,11)
DOUBLE PRECISION :: T,Z(NEQ),ZPRIME(NEQ),F1,F2,F3,F4
COMMON/AREA/S(NB),F1,F2,F3,F4,AX,BX,BY

!C    POLYNOMIAL EQUATIONS FOR THE INTERIOR NODES.

ZPRIME(1) = F1*(BY(2,1)*S(12)+SUM(BY(2,2:10)*Z(1:9))+BY(2,11)* S(13)) +F2* (BX(2,1)
      *S(2)+BX(2,2)*Z(1)+BX(2,3)*Z(10)+BX(2,4)*Z(19)+BX(2,5)*Z(28)+BX(2,6)*
      Z(37)+BX(2,7)*Z(46)+BX(2,8)*Z(55)+BX(2,9)*Z(64)+BX(2,10)*Z(73)+BX(2,
      11)*Z(82)+BX(2,12)*Z(91)+BX(2,13)*Z(100)+BX(2,14)*Z(109)+BX(2,15)*Z(1
      18)+BX(2,16)*Z(127)+BX(2,17)*Z(136)+BX(2,18)*Z(145)+BX(2,19)*Z(154)+B
      X(2,20)*S(49))-F3* (AX(2,1)*S(2)+AX(2,2)* Z(1)+AX(2,3) *Z(10)+AX(2,4)*
      Z(19) +AX(2,5)*Z(28)+AX(2,6)*Z(37)+AX(2,7)*Z(46)+AX(2,8)*Z(55)+AX(2,9)
      * Z(64)+AX(2,10)*Z(73)+AX(2,11)*Z(82)+AX(2,12)*Z(91)+AX(2,13)*Z(100)+
      AX(2,14)*Z(109)+AX(2,15)*Z(118)+AX(2,16)*Z(127)+ AX(2,17)*Z(136)+AX
      (2,18)* Z(145)+AX(2,19)*Z(154)+AX(2,20)*S(4l9))
ZPRIME(2) = F1* (BY(3,1)*S(12)+SUM(BY(3,2:10)*Z(1:9))+BY(3,11)*S(13)) +F2*(BX(2,1)*
      S(3)+BX(2,2)*Z(2)+BX(2,3)*Z(11)+BX(2,4)*Z(20)+BX(2,5)*Z(29)+BX(2,6)*Z(
      38)+BX(2,7)*Z(47)+BX(2,8)*Z(56)+BX(2,9)*Z(65)+BX(2,10)*Z(74)+BX(2,11)*
      Z(83)+BX(2,12)*Z(92)+BX(2,13)*Z(101)+BX(2,14)*Z(110)+BX(2,15)*Z(119)+
      BX(2,16)*Z(128)+BX(2,17)*Z(137)+BX(2,18)*Z(146)+BX(2,19)*Z(155)+BX(2,
      20)*S(50))-F3 *(AX(2,1)*S(3)+AX(2,2)*Z(2)+AX(2,3)*Z(11) +AX(2,4)* Z(20)+
      AX(2,5)*Z(29)+AX(2,6)*Z(38)+AX(2,7)*Z(47)+AX(2,8)*Z(56)+AX(2,9)*Z(65)
      +AX(2,10)*Z(74)+AX(2,11)*Z(83)+AX(2,12)*Z(92)+AX(2,13)*Z(101)+AX(2,1
      4)*Z(110)+AX(2,15)*Z(119)+AX(2,16)*Z(128)+AX(2,17)*Z(137)+AX(2,18)*Z(
      146)+AX(2,19)*Z(155)+AX(2,20)*S(50))
ZPRIME(3) = F1* (BY(4,1)*S(12)+SUM(BY(4,2:10)*Z(1:9))+BY(4,11)*S(13)) +F2*(BX(2,1)
      *S(4)+BX(2,2)*Z(3)+BX(2,3)*Z(12)+BX(2,4)*Z(21)+BX(2,5)*Z(30)+BX(2,6)*Z
      (39)+BX(2,7)*Z(48)+BX(2,8)*Z(57)+BX(2,9)*Z(66)+BX(2,10)*Z(75)+BX(2,11)
      *Z(84)+BX(2,12)*Z(93)+BX(2,13)*Z(102)+BX(2,14)*Z(111)+BX(2,15)*Z(120)
      +BX(2,16)*Z(129)+BX(2,17)*Z(138)+BX(2,18)*Z(147)+BX(2,19)*Z(156)+BX(
      2,20)*S(51))-F3* (AX(2,1)*S(4)+AX(2,2)*Z(3)+AX(2,3) *Z(12)+ AX(2,4)*Z(21)
      +AX(2,5)*Z(30)+AX(2,6)*Z(39)+AX(2,7)*Z(48)+AX(2,8)*Z(57)+AX(2,9)*Z(66
      )+AX(2,10)*Z(75)+AX(2,11)*Z(84)+AX(2,12)*Z(93)+AX(2,13)*Z(102)+AX(2,1
      4)*Z(111)+AX(2,15)*Z(120)+AX(2,16)*Z(129)+AX(2,17)*Z(138)+AX(2,18)*Z(
      147)+AX(2,19)*Z(156)+AX(2,20)*S(51))
ZPRIME(4) = F1* (BY(5,1)*S(12)+SUM(BY(5,2:10)*Z(1:9))+BY(5,11)*S(13)) +F2*(BX(2,1)*
      S(5)+BX(2,2)*Z(4)+BX(2,3)*Z(13)+BX(2,4)*Z(22)+BX(2,5)*Z(31)+BX(2,6)*Z(
      40)+BX(2,7)*Z(49)+BX(2,8)*Z(58)+BX(2,9)*Z(67)+BX(2,10)*Z(76)+BX(2,11)*
      Z(85)+BX(2,12)*Z(94)+BX(2,13)*Z(103)+BX(2,14)*Z(112)+BX(2,15)*Z(121)+
      BX(2,16)*Z(130)+BX(2,17)*Z(139)+BX(2,18)*Z(148)+BX(2,19)*Z(157)+BX(2,
      20)*S(52))-F3* (AX(2,1)*S(5)+AX(2,2)*Z(4)+AX(2,3)*Z(13)+AX(2,4)*Z(22)+
      AX(2,5)*Z(31)+AX(2,6)*Z(40)+AX(2,7)*Z(49)+AX(2,8)*Z(58)+AX(2,9)*Z(67)
      +AX(2,10)*Z(76)+AX(2,11)*Z(85)+AX(2,12)*Z(94)+AX(2,13)*Z(103)+AX(2,1
      4)*Z(112)+AX(2,15)*Z(121)+AX(2,16)*Z(130)+AX(2,17)*Z(139)+AX(2,18)*Z(
      148)+AX(2,19)*Z(157)+AX(2,20)*S(52))
ZPRIME(5) = F1* (BY(6,1)*S(12)+SUM(BY(6,2:10)*Z(1:9))+BY(6,11)*S(13))+F2*(BX(2,1)*
      S(6)+BX(2,2)*Z(5)+BX(2,3)*Z(14)+BX(2,4)*Z(23)+BX(2,5)*Z(32)+BX(2,6)*Z(
      41)+BX(2,7)*Z(50)+BX(2,8)*Z(59)+BX(2,9)*Z(68)+BX(2,10)*Z(77)+BX(2,11)*
      Z(86)+BX(2,12)*Z(95)+BX(2,13)*Z(104)+BX(2,14)*Z(113)+BX(2,15)*Z(122)+
      BX(2,16)*Z(131)+BX(2,17)*Z(140)+BX(2,18)*Z(149)+BX(2,19)*Z(158)+BX(2,
      20)* S(53))-F3* (AX(2,1)*S(6)+AX(2,2)*Z(5)+AX(2,3)*Z(14)+AX(2,4)*Z(23)+
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AX(2,5)*Z(32)+AX(2,6)*Z(41)+AX(2,7)*Z(50)+AX(2,8)*Z(59)+AX(2,9)*Z(68)
+AX(2,10)*Z(77)+AX(2,11)*Z(86)+AX(2,12)*Z(95)+AX(2,13)*Z(104)+AX(2,1
4)*Z(113)+AX(2,15)*Z(122)+AX(2,16)*Z(131)+AX(2,17)*Z(140)+AX(2,18)*Z(
149)+AX(2,19)*Z(158)+AX(2,20)*S(53))
ZPRIME(6) = F1* (BY(7,1)*S(12)+SUM(BY(7,2:10)*Z(1:9))+BY(7,11)*S(13))+F2*(BX(2,1)*
S(7)+BX(2,2)*Z(6)+BX(2,3)*Z(15)+BX(2,4)*Z(24)+BX(2,5)*Z(33)+BX(2,6)*Z(
42)+BX(2,7)*Z(51)+BX(2,8)*Z(60)+BX(2,9)*Z(69)+BX(2,10)*Z(78)+BX(2,11)*
Z(87)+BX(2,12)*Z(96)+BX(2,13)*Z(105)+BX(2,14)*Z(114)+BX(2,15)*Z(123)+
BX(2,16)*Z(132)+BX(2,17)*Z(141)+BX(2,18)*Z(150)+BX(2,19)*Z(159)+BX(2,
20)*S(54))-F3* (AX(2,1)*S(7)+AX(2,2)*Z(6)+AX(2,3)*Z(15)+AX(2,4)*Z(24)+
AX(2,5)*Z(33)+AX(2,6)*Z(42)+AX(2,7)*Z(51)+AX(2,8)*Z(60)+AX(2,9)*Z(69)
+AX(2,10)*Z(78)+AX(2,11)*Z(87)+AX(2,12)*Z(96)+AX(2,13)*Z(105)+AX(2,1
4)*Z(114)+AX(2,15)*Z(123)+AX(2,16)*Z(132)+AX(2,17)*Z(141)+AX(2,18)*Z(
150)+AX(2,19)*Z(159)+AX(2,20)*S(54))
ZPRIME(7) = F1 *(BY(8,1)*S(12)+SUM(BY(8,2:10)*Z(1:9))+BY(8,11)*S(13))+F2*(BX(2,1)*
S(8)+BX(2,2)*Z(7)+BX(2,3)*Z(16)+BX(2,4)*Z(25)+BX(2,5)*Z(34)+BX(2,6)*Z(
43)+BX(2,7)*Z(52)+BX(2,8)*Z(61)+BX(2,9)*Z(70)+BX(2,10)*Z(79)+BX(2,11)*
Z(88)+BX(2,12)*Z(97)+BX(2,13)*Z(106)+BX(2,14)*Z(115)+BX(2,15)*Z(124)+
BX(2,16)*Z(133)+BX(2,17)*Z(142)+BX(2,18)*Z(151)+BX(2,19)*Z(160)+BX(2,
20)*S(55))-F3*(AX(2,1)*S(8)+AX(2,2)*Z(7)+AX(2,3)*Z(16)+AX(2,4)*Z(25)+
AX(2,5)*Z(34)+AX(2,6)*Z(43)+AX(2,7)*Z(52)+AX(2,8)*Z(61)+AX(2,9)*Z(70)
+AX(2,10)*Z(79)+AX(2,11)*Z(88)+AX(2,12)*Z(97)+AX(2,13)*Z(106)+AX(2,1
4)*Z(115)+AX(2,15)*Z(124)+AX(2,16)*Z(133)+AX(2,17)*Z(142)+AX(2,18)*Z(
151)+AX(2,19)*Z(160)+AX(2,20)*S(55))
ZPRIME(8) = F1*(BY(9,1)*S(12)+SUM(BY(9,2:10)*Z(1:9))+BY(9,11)*S(13))+F2*(BX(2,1) *
S(9)+BX(2,2)*Z(8)+BX(2,3)*Z(17)+BX(2,4)*Z(26)+BX(2,5)*Z(35)+BX(2,6)*Z(
44)+BX(2,7)*Z(53)+BX(2,8)*Z(62)+BX(2,9)*Z(71)+BX(2,10)*Z(80)+BX(2,11)*
Z(89)+BX(2,12)*Z(98)+BX(2,13)*Z(107)+BX(2,14)*Z(116)+BX(2,15)*Z(125)+
BX(2,16)*Z(134)+BX(2,17)*Z(143)+BX(2,18)*Z(152)+BX(2,19)*Z(161)+BX(2,
20)*S(56))-F3*(AX(2,1)*S(9)+AX(2,2)*Z(8)+AX(2,3)*Z(17)+AX(2,4)*Z(26)+
AX(2,5)*Z(35)+AX(2,6)*Z(44)+AX(2,7)*Z(53)+AX(2,8)*Z(62)+AX(2,9)*Z(71)
+AX(2,10)*Z(80)+AX(2,11)*Z(89)+AX(2,12)*Z(98)+AX(2,13)*Z(107)+AX(2,1
4)*Z(116)+AX(2,15)*Z(125)+AX(2,16)*Z(134)+AX(2,17)*Z(143)+AX(2,18)*Z(
152)+AX(2,19)*Z(161)+AX(2,20)*S(56))

ZPRIME(9) = F1*(BY(10,1)*S(12)+SUM(BY(10,2:10)*Z(1:9))+BY(10,11)*S(13))+F2* (BX
(2,1)*S(10)+BX(2,2)*Z(9)+BX(2,3)*Z(18)+BX(2,4)*Z(27)+BX(2,5)* Z(36) +BX
(2,6)*Z(45)+BX(2,7)*Z(54)+BX(2,8)*Z(63)+BX(2,9)*Z(72)+BX(2,10)*Z(81)+
BX(2,11)*Z(90)+BX(2,12)*Z(99)+BX(2,13)*Z(108)+BX(2,14)*Z(117)+BX(2,15
)*Z(126)+BX(2,16)*Z(135)+BX(2,17)*Z(144)+BX(2,18) *Z(153)+ BX(2,19)*
Z(162)+BX(2,20)*S(57))-F3*(AX(2,1)*S(10)+AX(2,2)*Z(9)+AX(2,3)* Z(18)+
AX(2,4)* Z(27)+AX(2,5)*Z(36)+AX(2,6)*Z(45)+AX(2,7)*Z(54)+AX(2,8)*
Z(63) +AX(2,9)*Z(72)+AX(2,10)*Z(81)+AX(2,11)*Z(90)+AX(2,12)*Z(99)+ AX
(2,13)*Z(108)+AX(2,14)*Z(117)+AX(2,15)*Z(126)+AX(2,16)*Z(135)+ AX
(2,17)*Z(144)+AX(2,18)*Z(153)+AX(2,19)*Z(162)+AX(2,20)*S(57))
ZPRIME(10) = F1* (BY(2,1)*S(14)+SUM(BY(2,2:10)*Z(10:18))+BY(2,11)*S(15))+
F2*(BX(3,1)*S(2)+BX(3,2)*Z(1)+BX(3,3)*Z(10)+BX(3,4)*Z(19)+BX(3,5)*Z(28
)+BX(3,6)*Z(37)+BX(3,7)*Z(46)+BX(3,8)*Z(55)+BX(3,9)*Z(64)+BX(3,10)*Z(7
3)+BX(3,11)*Z(82)+BX(3,12)*Z(91)+BX(3,13)*Z(100)+BX(3,14)*Z(109)+BX(3
,15)*Z(118)+BX(3,16)*Z(127)+BX(3,17)*Z(136)+BX(3,18)*Z(145)+ BX (3,19)
*Z(154)+BX(3,20)*S(49))-F3*(AX(3,1)*S(2)+AX(3,2)*Z(1)+ AX(3,3) * Z(10)
+AX(3,4)*Z(19)+AX(3,5)*Z(28)+AX(3,6)*Z(37)+AX(3,7)* Z(46)+ AX (3,8) *
Z(55)+AX(3,9)*Z(64)+AX(3,10)*Z(73)+AX(3,11)*Z(82)+AX(3,12)*Z(91)+AX(
3,13)*Z(100)+AX(3,14)*Z(109)+AX(3,15)*Z(118)+AX(3,16)*Z(127)+AX(3,17)
*Z(136)+AX(3,18)*Z(145)+AX(3,19)*Z(154)+AX(3,20)*S(49))
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ZPRIME(11) = F1* (BY(3,1)*S(14)+SUM(BY(3,2:10)*Z(10:18))+BY(3,11)*S(15))+ F2*(BX
             (3,1)*S(3)+BX(3,2)*Z(2)+BX(3,3)*Z(11)+BX(3,4)*Z(20)+BX(3,5)*Z(29)+BX(3,
             6)*Z(38)+BX(3,7)*Z(47)+BX(3,8)*Z(56)+BX(3,9)*Z(65)+BX(3,10)*Z(74)+BX(
             3,11)*Z(83)+BX(3,12)*Z(92)+BX(3,13)*Z(101)+BX(3,14)*Z(110)+BX(3,15)*Z(
             119)+BX(3,16)*Z(128)+BX(3,17)*Z(137)+BX(3,18)*Z(146)+BX(3,19)*Z(155)+
             BX(3,20)*S(50))-F3*(AX(3,1)*S(3)+AX(3,2)*Z(2)+AX(3,3)*Z(11) +AX (3,4)*
             Z(20)+AX(3,5)*Z(29)+AX(3,6)*Z(38)+AX(3,7)*Z(47)+AX(3,8)*Z(56) +AX(3,9)
             *Z(65)+AX(3,10)*Z(74)+AX(3,11)*Z(83)+AX(3,12)*Z(92)+AX(3,13)*Z(101)+
             AX(3,14)*Z(110)+AX(3,15)*Z(119)+AX(3,16)*Z(128)+AX(3,17)*Z(137)+AX(3
             ,18)*Z(146)+AX(3,19)*Z(155)+AX(3,20)*S(50))
ZPRIME(12) = F1* (BY(4,1)*S(14)+SUM(BY(4,2:10)*Z(10:18))+BY(4,11)*S(15))+ F2*(BX
             (3,1)*S(4)+BX(3,2)*Z(3)+BX(3,3)*Z(12)+BX(3,4)*Z(21)+BX(3,5)*Z(30)+BX(3,
             6)*Z(39)+BX(3,7)*Z(48)+BX(3,8)*Z(57)+BX(3,9)*Z(66)+BX(3,10)*Z(75)+BX(
             3,11)*Z(84)+BX(3,12)*Z(93)+BX(3,13)*Z(102)+BX(3,14)*Z(111)+BX(3,15)*Z(
             120)+BX(3,16)*Z(129)+BX(3,17)*Z(138)+BX(3,18)*Z(147)+BX(3,19)*Z(156)+
             BX(3,20)*S(51))-F3* (AX(3,1)*S(4)+AX(3,2)*Z(3)+AX(3,3)*Z(12)+ AX (3,4)
             *Z(21)+AX(3,5)*Z(30)+AX(3,6)*Z(39)+AX(3,7)*Z(48)+AX(3,8)*Z(57) +AX
             (3,9)*Z(66)+AX(3,10)*Z(75)+AX(3,11)*Z(84)+AX(3,12)*Z(93)+AX(3,13)*Z(10
             2)+AX(3,14)*Z(111)+AX(3,15)*Z(120)+AX(3,16)*Z(129)+AX(3,17)*Z(138)+A
             X(3,18)*Z(147)+AX(3,19)*Z(156)+AX(3,20)*S(51))
ZPRIME(13) = F1* (BY(5,1)*S(14)+SUM(BY(5,2:10)*Z(10:18))+BY(5,11)*S(15))+F2*(BX
             (3,1)*S(5)+BX(3,2)*Z(4)+BX(3,3)*Z(13)+BX(3,4)*Z(22)+BX(3,5)*Z(31)+BX(3,
             6)*Z(40)+BX(3,7)*Z(49)+BX(3,8)*Z(58)+BX(3,9)*Z(67)+BX(3,10)*Z(76)+BX(
             3,11)*Z(85)+BX(3,12)*Z(94)+BX(3,13)*Z(103)+BX(3,14)*Z(112)+BX(3,15)*Z(
             121)+BX(3,16)*Z(130)+BX(3,17)*Z(139)+BX(3,18)*Z(148)+BX(3,19)*Z(157)+
             BX(3,20)*S(52))-F3*(AX(3,1)*S(5)+AX(3,2)*Z(4) +AX (3,3)*Z(13)+AX (3,4)
             *Z(22)+AX(3,5)*Z(31)+AX(3,6)*Z(40)+AX(3,7)*Z(49)+AX(3,8)*Z(58)+AX(3,9
             )*Z(67)+AX(3,10)*Z(76)+AX(3,11)*Z(85)+AX(3,12)*Z(94)+AX(3,13)*Z(103)+
             AX(3,14)*Z(112)+AX(3,15)*Z(121)+AX(3,16)*Z(130)+AX(3,17)*Z(139)+AX(3
             ,18)*Z(148)+AX(3,19)*Z(157)+AX(3,20)*S(52))
ZPRIME(14) = F1* (BY(6,1)*S(14)+SUM(BY(6,2:10)*Z(10:18))+BY(6,11)*S(15))+F2*(BX
             (3,1)*S(6)+BX(3,2)*Z(5)+BX(3,3)*Z(14)+BX(3,4)*Z(23)+BX(3,5)*Z(32)+BX(3,
             6)*Z(41)+BX(3,7)*Z(50)+BX(3,8)*Z(59)+BX(3,9)*Z(68)+BX(3,10)*Z(77)+BX(
             3,11)*Z(86)+BX(3,12)*Z(95)+BX(3,13)*Z(104)+BX(3,14)*Z(113)+BX(3,15)*Z(
             122)+BX(3,16)*Z(131)+BX(3,17)*Z(140)+BX(3,18)*Z(149)+BX(3,19)*Z(158)+
             BX(3,20)*S(53))-F3*(AX(3,1)*S(6)+AX(3,2)*Z(5)+AX (3,3)*Z(14)+AX (3,4)
             *Z(23)+AX(3,5)*Z(32)+AX(3,6)*Z(41)+AX(3,7)*Z(50)+AX(3,8)*Z(59)+AX(3,9
             )*Z(68)+AX(3,10)*Z(77)+AX(3,11)*Z(86)+AX(3,12)*Z(95)+AX(3,13)*Z(104)+
             AX(3,14)*Z(113)+AX(3,15)*Z(122)+AX(3,16)*Z(131)+AX(3,17)*Z(140)+AX(3
             ,18)*Z(149)+AX(3,19)*Z(158)+AX(3,20)*S(53))
ZPRIME(15) = F1* (BY(7,1)*S(14)+SUM(BY(7,2:10)*Z(10:18))+BY(7,11)*S(15))+F2*(BX
             (3,1)*S(7)+BX(3,2)*Z(6)+BX(3,3)*Z(15)+BX(3,4)*Z(24)+BX(3,5)*Z(33)+BX(3,
             6)*Z(42)+BX(3,7)*Z(51)+BX(3,8)*Z(60)+BX(3,9)*Z(69)+BX(3,10)*Z(78)+BX
             (3,11)*Z(87)+BX(3,12)*Z(96)+BX(3,13)*Z(105)+BX(3,14)*Z(114)+BX(3,15)*Z
             (123)+BX(3,16)*Z(132)+BX(3,17)*Z(141)+BX(3,18)*Z(150)+BX(3,19)*Z(159)
             +BX(3,20)*S(54))-F3*(AX(3,1)*S(7)+AX(3,2)*Z(6)+AX (3,3)*Z(15)+AX (3,4)
             *Z(24)+AX(3,5)*Z(33)+AX(3,6)*Z(42)+AX(3,7)*Z(51)+AX(3,8)*Z(60)+AX(3,9
             )*Z(69)+AX(3,10)*Z(78)+AX(3,11)*Z(87)+AX(3,12)*Z(96)+AX(3,13)*Z(105)+
             AX(3,14)*Z(114)+AX(3,15)*Z(123)+AX(3,16)*Z(132)+AX(3,17)*Z(141)+AX(3
             ,18)*Z(150)+AX(3,19)*Z(159)+AX(3,20)*S(54))
ZPRIME(16) = F1* (BY(8,1)*S(14)+SUM(BY(8,2:10)*Z(10:18))+BY(8,11)*S(15))+F2*(BX
             (3,1)*S(8)+BX(3,2)*Z(7)+BX(3,3)*Z(16)+BX(3,4)*Z(25)+BX(3,5)*Z(34)+BX(3,
             6)*Z(43)+BX(3,7)*Z(52)+BX(3,8)*Z(61)+BX(3,9)*Z(70)+BX(3,10)*Z(79)+BX
             (3,11)*Z(88)+BX(3,12)*Z(97)+BX(3,13)*Z(106)+BX(3,14)*Z(115)+BX(3,15)*Z
             (124)+BX(3,16)*Z(133)+BX(3,17)*Z(142)+BX(3,18)*Z(151)+BX(3,19)*Z(160)
             +BX(3,20)*S(55))-F3*(AX(3,1)*S(8)+AX(3,2)*Z(7)+AX(3,3)*Z(16)+AX (3,4)
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               *Z(25)+AX(3,5)*Z(34)+AX(3,6)*Z(43)+AX(3,7)*Z(52)+AX(3,8)*Z(61)+AX(3,9
               )*Z(70)+AX(3,10)*Z(79)+AX(3,11)*Z(88)+AX(3,12)*Z(97)+AX(3,13)*Z(106)+
               AX(3,14)*Z(115)+AX(3,15)*Z(124)+AX(3,16)*Z(133)+AX(3,17)*Z(142)+AX(3
               ,18)*Z(151)+AX(3,19)*Z(160)+AX(3,20)*S(55))
ZPRIME(17) = F1* (BY(9,1)*S(14)+SUM(BY(9,2:10)*Z(10:18))+BY(9,11)*S(15))+ F2*(BX
               (3,1)*S(9)+BX(3,2)*Z(8)+BX(3,3)*Z(17)+BX(3,4)*Z(26)+BX(3,5)*Z(35)+BX(3,
               6)*Z(44)+BX(3,7)*Z(53)+BX(3,8)*Z(62)+BX(3,9)*Z(71)+BX(3,10)*Z(80)+BX(
               3,11)*Z(89)+BX(3,12)*Z(98)+BX(3,13)*Z(107)+BX(3,14)*Z(116)+BX(3,15)*Z(
               125)+BX(3,16)*Z(134)+BX(3,17)*Z(143)+BX(3,18)*Z(152)+BX(3,19)*Z(161)+
               BX(3,20)*S(56))-F3*(AX(3,1)*S(9)+AX(3,2)*Z(8)+AX(3,3)* Z(17)+AX (3,4)
               *Z(26)+AX(3,5)*Z(35)+AX(3,6)*Z(44)+AX(3,7)*Z(53)+AX(3,8)*Z(62)+AX(3,9
               )*Z(71)+AX(3,10)*Z(80)+AX(3,11)*Z(89)+AX(3,12)*Z(98)+AX(3,13)*Z(107)+
               AX(3,14)*Z(116)+AX(3,15)*Z(125)+AX(3,16)*Z(134)+AX(3,17)*Z(143)+AX(3
               ,18)*Z(152)+AX(3,19)*Z(161)+AX(3,20)*S(56))

ZPRIME(18) = F1*(BY(10,1)*S(14)+SUM(BY(10,2:10)*Z(10:18))+BY(10,11)*S(15))+F2* (BX
               (3,1)*S(10)+BX(3,2)*Z(9)+BX(3,3)*Z(18)+BX(3,4)*Z(27)+BX(3,5)*Z(36)+BX(
               3,6)*Z(45)+BX(3,7)*Z(54)+BX(3,8)*Z(63)+BX(3,9)*Z(72)+BX(3,10)*Z(81)+B
               X(3,11)*Z(90)+BX(3,12)*Z(99)+BX(3,13)*Z(108)+BX(3,14)*Z(117)+BX(3,15)*
               Z(126)+BX(3,16)*Z(135)+BX(3,17)*Z(144)+BX(3,18)*Z(153)+BX(3,19)*Z(162
               )+BX(3,20)*S(57))-F3*(AX(3,1)*S(10)+AX(3,2)*Z(9)+AX (3,3)*Z(18)+AX(3,4)
               *Z(27)+AX(3,5)*Z(36)+AX(3,6)*Z(45)+AX(3,7)*Z(54)+ AX(3,8)*Z(63)+AX
               (3,9) *Z(72)+AX(3,10)*Z(81)+AX(3,11)*Z(90)+AX (3,12)*Z(99)+AX(3,13) *
               Z(108)+AX(3,14)*Z(117)+AX(3,15)*Z(126)+AX(3,16)*Z(135)+AX(3,17)*Z(144
               )+AX(3,18)*Z(153)+AX(3,19)*Z(162)+AX(3,20)*S(57))
ZPRIME(19) = F1* (BY(2,1)*S(16)+SUM(BY(2,2:10)*Z(19:27))+BY(2,11)*S(17))+ F2*(BX
               (4,1)*S(2)+BX(4,2)*Z(1)+BX(4,3)*Z(10)+BX(4,4)*Z(19)+BX(4,5)*Z(28)+BX(4,
               6)*Z(37)+BX(4,7)*Z(46)+BX(4,8)*Z(55)+BX(4,9)*Z(64)+BX(4,10)*Z(73)+BX(
               4,11)*Z(82)+BX(4,12)*Z(91)+BX(4,13)*Z(100)+BX(4,14)*Z(109)+BX(4,15)*Z(
               118)+BX(4,16)*Z(127)+BX(4,17)*Z(136)+BX(4,18)*Z(145)+BX(4,19)*Z(154)+
               BX(4,20)*S(49))-F3*(AX(4,1)*S(2)+AX(4,2)*Z(1)+AX(4,3) *Z(10)+ AX (4,4)*
               Z(19)+AX(4,5)*Z(28)+AX(4,6)*Z(37)+AX(4,7)*Z(46) +AX(4,8) *Z(55) +AX
               (4,9)*Z(64)+AX(4,10)*Z(73)+AX(4,11)*Z(82)+AX(4,12)*Z(91)+AX(4,13)*Z(10
               0)+AX(4,14)*Z(109)+AX(4,15)*Z(118)+AX(4,16)*Z(127)+AX(4,17)*Z(136)+A
               X(4,18)*Z(145)+AX(4,19)*Z(154)+AX(4,20)*S(49))
ZPRIME(20) = F1*(BY(3,1)*S(16)+SUM(BY(3,2:10)*Z(19:27))+BY(3,11)*S(17))+F2*(BX
               (4,1)*S(3)+BX(4,2)*Z(2)+BX(4,3)*Z(11)+BX(4,4)*Z(20)+BX(4,5)*Z(29)+BX(4,
               6)*Z(38)+BX(4,7)*Z(47)+BX(4,8)*Z(56)+BX(4,9)*Z(65)+BX(4,10)*Z(74)+BX(
               4,11)*Z(83)+BX(4,12)*Z(92)+BX(4,13)*Z(101)+BX(4,14)*Z(110)+BX(4,15)*Z(
               119)+BX(4,16)*Z(128)+BX(4,17)*Z(137)+BX(4,18)*Z(146)+BX(4,19)*Z(155)+
               BX(4,20)*S(50))-F3*(AX(4,1)*S(3)+AX(4,2)*Z(2)+AX(4,3)*Z(11) +AX (4,4)
               *Z(20)+AX(4,5)*Z(29)+AX(4,6)*Z(38)+AX(4,7)*Z(47)+AX(4,8)*Z(56)+AX(4,9
               )*Z(65)+AX(4,10)*Z(74)+AX(4,11)*Z(83)+AX(4,12)*Z(92)+AX(4,13)*Z(101)+
               AX(4,14)*Z(110)+AX(4,15)*Z(119)+AX(4,16)*Z(128)+AX(4,17)*Z(137)+AX(4
               ,18)*Z(146)+AX(4,19)*Z(155)+AX(4,20)*S(50))
ZPRIME(21) = F1* (BY(4,1)*S(16)+SUM(BY(4,2:10)*Z(19:27))+BY(4,11)*S(17))+F2* (BX
               (4,1)*S(4)+BX(4,2)*Z(3)+BX(4,3)*Z(12)+BX(4,4)*Z(21)+BX(4,5)*Z(30)+BX(4,
               6)*Z(39)+BX(4,7)*Z(48)+BX(4,8)*Z(57)+BX(4,9)*Z(66)+BX(4,10)*Z(75)+BX(
               4,11)*Z(84)+BX(4,12)*Z(93)+BX(4,13)*Z(102)+BX(4,14)*Z(111)+BX(4,15)*Z(
               120)+BX(4,16)*Z(129)+BX(4,17)*Z(138)+BX(4,18)*Z(147)+BX(4,19)*Z(156)+
               BX(4,20)*S(51))-F3*(AX(4,1)*S(4)+AX(4,2)*Z(3)+AX(4,3)*Z(12)+AX (4,4)
               *Z(21)+AX(4,5)*Z(30)+AX(4,6)*Z(39)+AX(4,7)*Z(48)+AX(4,8)*Z(57)+AX(4,9
               )*Z(66)+AX(4,10)*Z(75)+AX(4,11)*Z(84)+AX(4,12)*Z(93)+AX(4,13)*Z(102)+
               AX(4,14)*Z(111)+AX(4,15)*Z(120)+AX(4,16)*Z(129)+AX(4,17)*Z(138)+AX(4
               ,18)*Z(147)+AX(4,19)*Z(156)+AX(4,20)*S(51))
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ZPRIME(22) = F1* (BY(5,1)*S(16)+SUM(BY(5,2:10)*Z(19:27))+BY(5,11)*S(17))+F2*(BX
             (4,1)*S(5)+BX(4,2)*Z(4)+BX(4,3)*Z(13)+BX(4,4)*Z(22)+BX(4,5)*Z(31)+BX(4,
             6)*Z(40)+BX(4,7)*Z(49)+BX(4,8)*Z(58)+BX(4,9)*Z(67)+BX(4,10)*Z(76)+BX(
             4,11)*Z(85)+BX(4,12)*Z(94)+BX(4,13)*Z(103)+BX(4,14)*Z(112)+BX(4,15)*Z(
             121)+BX(4,16)*Z(130)+BX(4,17)*Z(139)+BX(4,18)*Z(148)+BX(4,19)*Z(157)+
             BX(4,20)*S(52))-F3*(AX(4,1)*S(5)+AX(4,2)*Z(4)+AX(4,3)*Z(13)+AX (4,4)
             *Z(22)+AX(4,5)*Z(31)+AX(4,6)*Z(40)+AX(4,7)*Z(49)+AX(4,8)*Z(58)+AX(4,9
             )*Z(67)+AX(4,10)*Z(76)+AX(4,11)*Z(85)+AX(4,12)*Z(94)+AX(4,13)*Z(103)+
             AX(4,14)*Z(112)+AX(4,15)*Z(121)+AX(4,16)*Z(130)+AX(4,17)*Z(139)+AX(4
             ,18)*Z(148)+AX(4,19)*Z(157)+AX(4,20)*S(52))
ZPRIME(23) = F1* (BY(6,1)*S(16)+SUM(BY(6,2:10)*Z(19:27))+BY(6,11)*S(17))+F2*(BX
             (4,1)*S(6)+BX(4,2)*Z(5)+BX(4,3)*Z(14)+BX(4,4)*Z(23)+BX(4,5)*Z(32)+BX(4,
             6)*Z(41)+BX(4,7)*Z(50)+BX(4,8)*Z(59)+BX(4,9)*Z(68)+BX(4,10)*Z(77)+BX(
             4,11)*Z(86)+BX(4,12)*Z(95)+BX(4,13)*Z(104)+BX(4,14)*Z(113)+BX(4,15)*Z(
             122)+BX(4,16)*Z(131)+BX(4,17)*Z(140)+BX(4,18)*Z(149)+BX(4,19)*Z(158)+
             BX(4,20)*S(53))-F3*(AX(4,1)*S(6)+AX(4,2)*Z(5)+AX(4,3)*Z(14)+AX (4,4)
             *Z(23)+AX(4,5)*Z(32)+AX(4,6)*Z(41)+AX(4,7)*Z(50)+AX(4,8)*Z(59)+AX(4,9
             )*Z(68)+AX(4,10)*Z(77)+AX(4,11)*Z(86)+AX(4,12)*Z(95)+AX(4,13)*Z(104)+
             AX(4,14)*Z(113)+AX(4,15)*Z(122)+AX(4,16)*Z(131)+AX(4,17)*Z(140)+AX(4
             ,18)*Z(149)+AX(4,19)*Z(158)+AX(4,20)*S(53))
ZPRIME(24) = F1* (BY(7,1)*S(16)+SUM(BY(7,2:10)*Z(19:27))+BY(7,11)*S(17))+F2*(BX
             (4,1)*S(7)+BX(4,2)*Z(6)+BX(4,3)*Z(15)+BX(4,4)*Z(24)+BX(4,5)*Z(33)+BX(4,
             6)*Z(42)+BX(4,7)*Z(51)+BX(4,8)*Z(60)+BX(4,9)*Z(69)+BX(4,10)*Z(78)+BX(
             4,11)*Z(87)+BX(4,12)*Z(96)+BX(4,13)*Z(105)+BX(4,14)*Z(114)+BX(4,15)*Z(
             123)+BX(4,16)*Z(132)+BX(4,17)*Z(141)+BX(4,18)*Z(150)+BX(4,19)*Z(159)+
             BX(4,20)*S(54))-F3*(AX(4,1)*S(7)+AX(4,2)*Z(6)+AX(4,3)*Z(15)+AX (4,4)
             *Z(24)+AX(4,5)*Z(33)+AX(4,6)*Z(42)+AX(4,7)*Z(51)+AX(4,8)*Z(60)+AX(4,9
             )*Z(69)+AX(4,10)*Z(78)+AX(4,11)*Z(87)+AX(4,12)*Z(96)+AX(4,13)*Z(105)+
             AX(4,14)*Z(114)+AX(4,15)*Z(123)+AX(4,16)*Z(132)+AX(4,17)*Z(141)+AX(4
             ,18)*Z(150)+AX(4,19)*Z(159)+AX(4,20)*S(54))
ZPRIME(25) = F1* (BY(8,1)*S(16)+SUM(BY(8,2:10)*Z(19:27))+BY(8,11)*S(17))+F2*(BX
             (4,1)*S(8)+BX(4,2)*Z(7)+BX(4,3)*Z(16)+BX(4,4)*Z(25)+BX(4,5)*Z(34)+BX(4,
             6)*Z(43)+BX(4,7)*Z(52)+BX(4,8)*Z(61)+BX(4,9)*Z(70)+BX(4,10)*Z(79)+BX(
             4,11)*Z(88)+BX(4,12)*Z(97)+BX(4,13)*Z(106)+BX(4,14)*Z(115)+BX(4,15)*Z(
             124)+BX(4,16)*Z(133)+BX(4,17)*Z(142)+BX(4,18)*Z(151)+BX(4,19)*Z(160)+
             BX(4,20)*S(55))-F3*(AX(4,1)*S(8)+AX(4,2)*Z(7)+AX(4,3)*Z(16)+AX (4,4)
             *Z(25)+AX(4,5)*Z(34)+AX(4,6)*Z(43)+AX(4,7)*Z(52)+AX(4,8)*Z(61)+AX(4,9
             )*Z(70)+AX(4,10)*Z(79)+AX(4,11)*Z(88)+AX(4,12)*Z(97)+AX(4,13)*Z(106)+
             AX(4,14)*Z(115)+AX(4,15)*Z(124)+AX(4,16)*Z(133)+AX(4,17)*Z(142)+AX(4
             ,18)*Z(151)+AX(4,19)*Z(160)+AX(4,20)*S(55))
ZPRIME(26) = F1* (BY(9,1)*S(16)+SUM(BY(9,2:10)*Z(19:27))+BY(9,11)*S(17))+F2*(BX
             (4,1)*S(9)+BX(4,2)*Z(8)+BX(4,3)*Z(17)+BX(4,4)*Z(26)+BX(4,5)*Z(35)+BX(4,
             6)*Z(44)+BX(4,7)*Z(53)+BX(4,8)*Z(62)+BX(4,9)*Z(71)+BX(4,10)*Z(80)+BX(
             4,11)*Z(89)+BX(4,12)*Z(98)+BX(4,13)*Z(107)+BX(4,14)*Z(116)+BX(4,15)*Z(
             125)+BX(4,16)*Z(134)+BX(4,17)*Z(143)+BX(4,18)*Z(152)+BX(4,19)*Z(161)+
             BX(4,20)*S(56))-F3*(AX(4,1)*S(9)+AX(4,2)*Z(8)+AX(4,3)*Z(17)+AX (4,4)
             *Z(26)+AX(4,5)*Z(35)+AX(4,6)*Z(44)+AX(4,7)*Z(53)+AX(4,8)*Z(62)+AX(4,9
             )*Z(71)+AX(4,10)*Z(80)+AX(4,11)*Z(89)+AX(4,12)*Z(98)+AX(4,13)*Z(107)+
             AX(4,14)*Z(116)+AX(4,15)*Z(125)+AX(4,16)*Z(134)+AX(4,17)*Z(143)+AX(4
             ,18)*Z(152)+AX(4,19)*Z(161)+AX(4,20)*S(56))
ZPRIME(27) = F1* (BY(10,1)*S(16)+SUM(BY(10,2:10)*Z(19:27))+BY(10,11)*S(17))+F2*
             (BX(4,1)*S(10)+BX(4,2)*Z(9)+BX(4,3)*Z(18)+BX(4,4)*Z(27)+BX(4,5)*Z(36)+
             BX(4,6)*Z(45)+BX(4,7)*Z(54)+BX(4,8)*Z(63)+BX(4,9)*Z(72)+BX(4,10)*Z(81)
             +BX(4,11)*Z(90)+BX(4,12)*Z(99)+BX(4,13)*Z(108)+BX(4,14)*Z(117)+BX(4,1
             5)*Z(126)+BX(4,16)*Z(135)+BX(4,17)*Z(144)+BX(4,18)*Z(153)+BX(4,19)*Z(
             162)+BX(4,20)*S(57))-F3*(AX(4,1)*S(10)+AX(4,2)*Z(9)+AX(4,3)*
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Z(18)+AX(4,4)*Z(27)+AX(4,5)*Z(36)+AX(4,6)*Z(45)+AX(4,7)*Z(54)+AX(4,8)
*Z(63)+AX(4,9)*Z(72)+AX(4,10)*Z(81)+AX(4,11)*Z(90)+AX(4,12)*Z(99)+AX
(4,13)*Z(108)+AX(4,14)*Z(117)+AX(4,15)*Z(126)+AX(4,16)*Z(135)+AX(4,17)
*Z(144)+AX(4,18)*Z(153)+AX(4,19)*Z(162)+AX(4,20)*S(57))

ZPRIME(28) = F1* (BY(2,1)*S(18)+SUM(BY(2,2:10)*Z(28:36))+BY(2,11)*S(19))+F2*(BX
(5,1)*S(2)+BX(5,2)*Z(1)+BX(5,3)*Z(10)+BX(5,4)*Z(19)+BX(5,5)*Z(28)+BX(5,
6)*Z(37)+BX(5,7)*Z(46)+BX(5,8)*Z(55)+BX(5,9)*Z(64)+BX(5,10)*Z(73)+BX(
5,11)*Z(82)+BX(5,12)*Z(91)+BX(5,13)*Z(100)+BX(5,14)*Z(109)+BX(5,15)*Z(
118)+BX(5,16)*Z(127)+BX(5,17)*Z(136)+BX(5,18)*Z(145)+BX(5,19)*Z(154)+
BX(5,20)*S(49))-F3*(AX(5,1)*S(2)+AX(5,2)*Z(1)+AX(5,3)*Z(10)+AX (5,4)
*Z(19)+AX(5,5)*Z(28)+AX(5,6)*Z(37)+AX(5,7)*Z(46)+AX(5,8)*Z(55)+AX(5,9
)*Z(64)+AX(5,10)*Z(73)+AX(5,11)*Z(82)+AX(5,12)*Z(91)+AX(5,13)*Z(100)+
AX(5,14)*Z(109)+AX(5,15)*Z(118)+AX(5,16)*Z(127)+AX(5,17)*Z(136)+AX(5
,18)*Z(145)+AX(5,19)*Z(154)+AX(5,20)*S(49))

ZPRIME(29) = F1* (BY(3,1)*S(18)+SUM(BY(3,2:10)*Z(28:36))+BY(3,11)*S(19))+F2*(BX
(5,1)*S(3)+BX(5,2)*Z(2)+BX(5,3)*Z(11)+BX(5,4)*Z(20)+BX(5,5)*Z(29)+BX(5,
6)*Z(38)+BX(5,7)*Z(47)+BX(5,8)*Z(56)+BX(5,9)*Z(65)+BX(5,10)*Z(74)+BX(
5,11)*Z(83)+BX(5,12)*Z(92)+BX(5,13)*Z(101)+BX(5,14)*Z(110)+BX(5,15)*Z(
119)+BX(5,16)*Z(128)+BX(5,17)*Z(137)+BX(5,18)*Z(146)+BX(5,19)*Z(155)+
BX(5,20)*S(50))-F3*(AX(5,1)*S(3)+AX(5,2)*Z(2)+AX(5,3)*Z(11)+AX (5,4)
*Z(20)+AX(5,5)*Z(29)+AX(5,6)*Z(38)+AX(5,7)*Z(47)+AX(5,8)*Z(56)+AX(5,9
)*Z(65)+AX(5,10)*Z(74)+AX(5,11)*Z(83)+AX(5,12)*Z(92)+AX(5,13)*Z(101)+
AX(5,14)*Z(110)+AX(5,15)*Z(119)+AX(5,16)*Z(128)+AX(5,17)*Z(137)+AX(5
,18)*Z(146)+AX(5,19)*Z(155)+AX(5,20)*S(50))

ZPRIME(30) = F1* (BY(4,1)*S(18)+SUM(BY(4,2:10)*Z(28:36))+BY(4,11)*S(19))+F2*(BX
(5,1)*S(4)+BX(5,2)*Z(3)+BX(5,3)*Z(12)+BX(5,4)*Z(21)+BX(5,5)*Z(30)+BX(5,
6)*Z(39)+BX(5,7)*Z(48)+BX(5,8)*Z(57)+BX(5,9)*Z(66)+BX(5,10)*Z(75)+BX(
5,11)*Z(84)+BX(5,12)*Z(93)+BX(5,13)*Z(102)+BX(5,14)*Z(111)+BX(5,15)*Z(
120)+BX(5,16)*Z(129)+BX(5,17)*Z(138)+BX(5,18)*Z(147)+BX(5,19)*Z(156)+
BX(5,20)*S(51))-F3*(AX(5,1)*S(4)+AX(5,2)*Z(3)+AX(5,3)*Z(12)+AX (5,4)
*Z(21)+AX(5,5)*Z(30)+AX(5,6)*Z(39)+AX(5,7)*Z(48)+AX(5,8)*Z(57)+AX(5,9
)*Z(66)+AX(5,10)*Z(75)+AX(5,11)*Z(84)+AX(5,12)*Z(93)+AX(5,13)*Z(102)+
AX(5,14)*Z(111)+AX(5,15)*Z(120)+AX(5,16)*Z(129)+AX(5,17)*Z(138)+AX(5
,18)*Z(147)+AX(5,19)*Z(156)+AX(5,20)*S(51))

ZPRIME(31) = F1* (BY(5,1)*S(18)+SUM(BY(5,2:10)*Z(28:36))+BY(5,11)*S(19))+F2*(BX
(5,1)*S(5)+BX(5,2)*Z(4)+BX(5,3)*Z(13)+BX(5,4)*Z(22)+BX(5,5)*Z(31)+BX(5,
6)*Z(40)+BX(5,7)*Z(49)+BX(5,8)*Z(58)+BX(5,9)*Z(67)+BX(5,10)*Z(76)+BX(
5,11)*Z(85)+BX(5,12)*Z(94)+BX(5,13)*Z(103)+BX(5,14)*Z(112)+BX(5,15)*Z(
121)+BX(5,16)*Z(130)+BX(5,17)*Z(139)+BX(5,18)*Z(148)+BX(5,19)*Z(157)+
BX(5,20)*S(52))-F3*(AX(5,1)*S(5)+AX(5,2)*Z(4)+AX(5,3)*Z(13)+AX (5,4)
*Z(22)+AX(5,5)*Z(31)+AX(5,6)*Z(40)+AX(5,7)*Z(49)+AX(5,8)*Z(58)+AX(5,9
)*Z(67)+AX(5,10)*Z(76)+AX(5,11)*Z(85)+AX(5,12)*Z(94)+AX(5,13)*Z(103)+
AX(5,14)*Z(112)+AX(5,15)*Z(121)+AX(5,16)*Z(130)+AX(5,17)*Z(139)+AX(5
,18)*Z(148)+AX(5,19)*Z(157)+AX(5,20)*S(52))

ZPRIME(32) = F1* (BY(6,1)*S(18)+SUM(BY(6,2:10)*Z(28:36))+BY(6,11)*S(19))+F2*(BX
(5,1)*S(6)+BX(5,2)*Z(5)+BX(5,3)*Z(14)+BX(5,4)*Z(23)+BX(5,5)*Z(32)+BX(5,
6)*Z(41)+BX(5,7)*Z(50)+BX(5,8)*Z(59)+BX(5,9)*Z(68)+BX(5,10)*Z(77)+BX(
5,11)*Z(86)+BX(5,12)*Z(95)+BX(5,13)*Z(104)+BX(5,14)*Z(113)+BX(5,15)*Z(
122)+BX(5,16)*Z(131)+BX(5,17)*Z(140)+BX(5,18)*Z(149)+BX(5,19)*Z(158)+
BX(5,20)*S(53))-F3*(AX(5,1)*S(6)+AX(5,2)*Z(5)+AX(5,3)*Z(14)+AX (5,4)
*Z(23)+AX(5,5)*Z(32)+AX(5,6)*Z(41)+AX(5,7)*Z(50)+AX(5,8)*Z(59)+AX(5,9
)*Z(68)+AX(5,10)*Z(77)+AX(5,11)*Z(86)+AX(5,12)*Z(95)+AX(5,13)*Z(104)+
AX(5,14)*Z(113)+AX(5,15)*Z(122)+AX(5,16)*Z(131)+AX(5,17)*Z(140)+AX(5
,18)*Z(149)+AX(5,19)*Z(158)+AX(5,20)*S(53))

ZPRIME(33) = F1*(BY(7,1)*S(18)+SUM(BY(7,2:10)*Z(28:36))+BY(7,11)*S(19))+F2*(BX
(5,1)*S(7)+BX(5,2)*Z(6)+BX(5,3)*Z(15)+BX(5,4)*Z(24)+BX(5,5)*Z(33)+BX(5,

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              6)*Z(42)+BX(5,7)*Z(51)+BX(5,8)*Z(60)+BX(5,9)*Z(69)+BX(5,10)*Z(78)+BX(
              5,11)*Z(87)+BX(5,12)*Z(96)+BX(5,13)*Z(105)+BX(5,14)*Z(114)+BX(5,15)*Z(
              123)+BX(5,16)*Z(132)+BX(5,17)*Z(141)+BX(5,18)*Z(150)+BX(5,19)*Z(159)+
              BX(5,20)*S(54))-F3*(AX(5,1)*S(7)+AX(5,2)*Z(6)+AX(5,3)*Z(15)+AX (5,4)
              *Z(24)+AX(5,5)*Z(33)+AX(5,6)*Z(42)+AX(5,7)*Z(51)+AX(5,8)*Z(60)+AX(5,9
              )*Z(69)+AX(5,10)*Z(78)+AX(5,11)*Z(87)+AX(5,12)*Z(96)+AX(5,13)*Z(105)+
              AX(5,14)*Z(114)+AX(5,15)*Z(123)+AX(5,16)*Z(132)+AX(5,17)*Z(141)+AX(5
              ,18)*Z(150)+AX(5,19)*Z(159)+AX(5,20)*S(54))
ZPRIME(34) = F1* (BY(8,1)*S(18)+SUM(BY(8,2:10)*Z(28:36))+BY(8,11)*S(19))+F2*(BX
              (5,1)*S(8)+BX(5,2)*Z(7)+BX(5,3)*Z(16)+BX(5,4)*Z(25)+BX(5,5)*Z(34)+BX(5,
              6)*Z(43)+BX(5,7)*Z(52)+BX(5,8)*Z(61)+BX(5,9)*Z(70)+BX(5,10)*Z(79)+BX(
              5,11)*Z(88)+BX(5,12)*Z(97)+BX(5,13)*Z(106)+BX(5,14)*Z(115)+BX(5,15)*Z(
              124)+BX(5,16)*Z(133)+BX(5,17)*Z(142)+BX(5,18)*Z(151)+BX(5,19)*Z(160)+
              BX(5,20)*S(55))-F3*(AX(5,1)*S(8)+AX(5,2)*Z(7)+AX(5,3)*Z(16)+AX (5,4)
              *Z(25)+AX(5,5)*Z(34)+AX(5,6)*Z(43)+AX(5,7)*Z(52)+AX(5,8)*Z(61)+AX(5,9
              )*Z(70)+AX(5,10)*Z(79)+AX(5,11)*Z(88)+AX(5,12)*Z(97)+AX(5,13)*Z(106)+
              AX(5,14)*Z(115)+AX(5,15)*Z(124)+AX(5,16)*Z(133)+AX(5,17)*Z(142)+AX(5
              ,18)*Z(151)+AX(5,19)*Z(160)+AX(5,20)*S(55))
ZPRIME(35) = F1* (BY(9,1)*S(18)+SUM(BY(9,2:10)*Z(28:36))+BY(9,11)*S(19))+F2*(BX
              (5,1)*S(9)+BX(5,2)*Z(8)+BX(5,3)*Z(17)+BX(5,4)*Z(26)+BX(5,5)*Z(35)+BX(5,
              6)*Z(44)+BX(5,7)*Z(53)+BX(5,8)*Z(62)+BX(5,9)*Z(71)+BX(5,10)*Z(80)+BX(
              5,11)*Z(89)+BX(5,12)*Z(98)+BX(5,13)*Z(107)+BX(5,14)*Z(116)+BX(5,15)*Z(
              125)+BX(5,16)*Z(134)+BX(5,17)*Z(143)+BX(5,18)*Z(152)+BX(5,19)*Z(161)+
              BX(5,20)*S(56))-F3*(AX(5,1)*S(9)+AX(5,2)*Z(8)+AX(5,3)*Z(17)+AX (5,4)
              *Z(26)+AX(5,5)*Z(35)+AX(5,6)*Z(44)+AX(5,7)*Z(53)+AX(5,8)*Z(62)+AX(5,9
              )*Z(71)+AX(5,10)*Z(80)+AX(5,11)*Z(89)+AX(5,12)*Z(98)+AX(5,13)*Z(107)+
              AX(5,14)*Z(116)+AX(5,15)*Z(125)+AX(5,16)*Z(134)+AX(5,17)*Z(143)+AX(5
              ,18)*Z(152)+AX(5,19)*Z(161)+AX(5,20)*S(56))
ZPRIME(36) = F1*(BY(10,1)*S(18)+SUM(BY(10,2:10)*Z(28:36))+BY(10,11)*S(19))+F2*(BX
              (5,1)*S(10)+BX(5,2)*Z(9)+BX(5,3)*Z(18)+BX(5,4)*Z(27)+BX(5,5)*Z(36)+BX(
              5,6)*Z(45)+BX(5,7)*Z(54)+BX(5,8)*Z(63)+BX(5,9)*Z(72)+BX(5,10)*Z(81)+B
              X(5,11)*Z(90)+BX(5,12)*Z(99)+BX(5,13)*Z(108)+BX(5,14)*Z(117)+BX(5,15)*
              Z(126)+BX(5,16)*Z(135)+BX(5,17)*Z(144)+BX(5,18)*Z(153)+BX(5,19)*Z(162
              )+BX(5,20)*S(57))-F3*(AX(5,1)*S(10)+AX(5,2)*Z(9)+AX(5,3)*Z(18)+AX (5,4)
              *Z(27)+AX(5,5)*Z(36)+AX(5,6)*Z(45)+AX(5,7)*Z(54)+AX(5,8)*Z(63)+AX(5,9
              )*Z(72)+AX(5,10)*Z(81)+AX(5,11)*Z(90)+AX(5,12)*Z(99)+AX(5,13)*Z(108)+
              AX(5,14)*Z(117)+AX(5,15)*Z(126)+AX(5,16)*Z(135)+AX(5,17)*Z(144)+AX(5
              ,18)*Z(153)+AX(5,19)*Z(162)+AX(5,20)*S(57))
ZPRIME(37) = F1* (BY(2,1)*S(20)+SUM(BY(2,2:10)*Z(37:45))+BY(2,11)*S(21))+F2*(BX
              (6,1)*S(2)+BX(6,2)*Z(1)+BX(6,3)*Z(10)+BX(6,4)*Z(19)+BX(6,5)*Z(28)+BX(6,
              6)*Z(37)+BX(6,7)*Z(46)+BX(6,8)*Z(55)+BX(6,9)*Z(64)+BX(6,10)*Z(73)+BX(
              6,11)*Z(82)+BX(6,12)*Z(91)+BX(6,13)*Z(100)+BX(6,14)*Z(109)+BX(6,15)*Z(
              118)+BX(6,16)*Z(127)+BX(6,17)*Z(136)+BX(6,18)*Z(145)+BX(6,19)*Z(154)+
              BX(6,20)*S(49))-F3*(AX(6,1)*S(2)+AX(6,2)*Z(1)+AX(6,3)*Z(10)+AX (6,4)
              *Z(19)+AX(6,5)*Z(28)+AX(6,6)*Z(37)+AX(6,7)*Z(46)+AX(6,8)*Z(55)+AX(6,9
              )*Z(64)+AX(6,10)*Z(73)+AX(6,11)*Z(82)+AX(6,12)*Z(91)+AX(6,13)*Z(100)+
              AX(6,14)*Z(109)+AX(6,15)*Z(118)+AX(6,16)*Z(127)+AX(6,17)*Z(136)+AX(6
              ,18)*Z(145)+AX(6,19)*Z(154)+AX(6,20)*S(49))
ZPRIME(38) = F1* (BY(3,1)*S(20)+SUM(BY(3,2:10)*Z(37:45))+BY(3,11)*S(21))+F2*(BX
              (6,1)*S(3)+BX(6,2)*Z(2)+BX(6,3)*Z(11)+BX(6,4)*Z(20)+BX(6,5)*Z(29)+BX(6,
              6)*Z(38)+BX(6,7)*Z(47)+BX(6,8)*Z(56)+BX(6,9)*Z(65)+BX(6,10)*Z(74)+BX(
              6,11)*Z(83)+BX(6,12)*Z(92)+BX(6,13)*Z(101)+BX(6,14)*Z(110)+BX(6,15)*Z(
              119)+BX(6,16)*Z(128)+BX(6,17)*Z(137)+BX(6,18)*Z(146)+BX(6,19)*Z(155)+
              BX(6,20)*S(50))-F3*(AX(6,1)*S(3)+AX(6,2)*Z(2)+AX(6,3)*Z(11)+AX (6,4)
              *Z(20)+AX(6,5)*Z(29)+AX(6,6)*Z(38)+AX(6,7)*Z(47)+AX(6,8)*Z(56)+AX(6,9
              )*Z(65)+AX(6,10)*Z(74)+AX(6,11)*Z(83)+AX(6,12)*Z(92)+AX(6,13)*Z(101)+
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               AX(6,14)*Z(110)+AX(6,15)*Z(119)+AX(6,16)*Z(128)+AX(6,17)*Z(137)+AX(6
               ,18)*Z(146)+AX(6,19)*Z(155)+AX(6,20)*S(50))
ZPRIME(39) = F1* (BY(4,1)*S(20)+SUM(BY(4,2:10)*Z(37:45))+BY(4,11)*S(21))+F2*(BX
               (6,1)*S(4)+BX(6,2)*Z(3)+BX(6,3)*Z(12)+BX(6,4)*Z(21)+BX(6,5)*Z(30)+BX(6,
               6)*Z(39)+BX(6,7)*Z(48)+BX(6,8)*Z(57)+BX(6,9)*Z(66)+BX(6,10)*Z(75)+BX(
               6,11)*Z(84)+BX(6,12)*Z(93)+BX(6,13)*Z(102)+BX(6,14)*Z(111)+BX(6,15)*Z(
               120)+BX(6,16)*Z(129)+BX(6,17)*Z(138)+BX(6,18)*Z(147)+BX(6,19)*Z(156)+
               BX(6,20)*S(51))-F3*(AX(6,1)*S(4)+AX(6,2)*Z(3)+AX(6,3)*Z(12)+AX (6,4)
               *Z(21)+AX(6,5)*Z(30)+AX(6,6)*Z(39)+AX(6,7)*Z(48)+AX(6,8)*Z(57)+AX(6,9
               )*Z(66)+AX(6,10)*Z(75)+AX(6,11)*Z(84)+AX(6,12)*Z(93)+AX(6,13)*Z(102)+
               AX(6,14)*Z(111)+AX(6,15)*Z(120)+AX(6,16)*Z(129)+AX(6,17)*Z(138)+AX(6
               ,18)*Z(147)+AX(6,19)*Z(156)+AX(6,20)*S(51))
ZPRIME(40) = F1* (BY(5,1)*S(20)+SUM(BY(5,2:10)*Z(37:45))+BY(5,11)*S(21))+F2*(BX
               (6,1)*S(5)+BX(6,2)*Z(4)+BX(6,3)*Z(13)+BX(6,4)*Z(22)+BX(6,5)*Z(31)+BX(6,
               6)*Z(40)+BX(6,7)*Z(49)+BX(6,8)*Z(58)+BX(6,9)*Z(67)+BX(6,10)*Z(76)+BX(
               6,11)*Z(85)+BX(6,12)*Z(94)+BX(6,13)*Z(103)+BX(6,14)*Z(112)+BX(6,15)*Z(
               121)+BX(6,16)*Z(130)+BX(6,17)*Z(139)+BX(6,18)*Z(148)+BX(6,19)*Z(157)+
               BX(6,20)*S(52))-F3*(AX(6,1)*S(5)+AX(6,2)*Z(4)+AX(6,3)*Z(13)+AX (6,4)
               *Z(22)+AX(6,5)*Z(31)+AX(6,6)*Z(40)+AX(6,7)*Z(49)+AX(6,8)*Z(58)+AX(6,9
               )*Z(67)+AX(6,10)*Z(76)+AX(6,11)*Z(85)+AX(6,12)*Z(94)+AX(6,13)*Z(103)+
               AX(6,14)*Z(112)+AX(6,15)*Z(121)+AX(6,16)*Z(130)+AX(6,17)*Z(139)+AX(6
               ,18)*Z(148)+AX(6,19)*Z(157)+AX(6,20)*S(52))
ZPRIME(41) = F1* (BY(6,1)*S(20)+SUM(BY(6,2:10)*Z(37:45))+BY(6,11)*S(21))+F2*(BX
               (6,1)*S(6)+BX(6,2)*Z(5)+BX(6,3)*Z(14)+BX(6,4)*Z(23)+BX(6,5)*Z(32)+BX(6,
               6)*Z(41)+BX(6,7)*Z(50)+BX(6,8)*Z(59)+BX(6,9)*Z(68)+BX(6,10)*Z(77)+BX(
               6,11)*Z(86)+BX(6,12)*Z(95)+BX(6,13)*Z(104)+BX(6,14)*Z(113)+BX(6,15)*Z(
               122)+BX(6,16)*Z(131)+BX(6,17)*Z(140)+BX(6,18)*Z(149)+BX(6,19)*Z(158)+
               BX(6,20)*S(53))-F3*(AX(6,1)*S(6)+AX(6,2)*Z(5)+AX(6,3)*Z(14)+AX (6,4)
               *Z(23)+AX(6,5)*Z(32)+AX(6,6)*Z(41)+AX(6,7)*Z(50)+AX(6,8)*Z(59)+AX(6,9
               )*Z(68)+AX(6,10)*Z(77)+AX(6,11)*Z(86)+AX(6,12)*Z(95)+AX(6,13)*Z(104)+
               AX(6,14)*Z(113)+AX(6,15)*Z(122)+AX(6,16)*Z(131)+AX(6,17)*Z(140)+AX(6
               ,18)*Z(149)+AX(6,19)*Z(158)+AX(6,20)*S(53))
ZPRIME(42) = F1* (BY(7,1)*S(20)+SUM(BY(7,2:10)*Z(37:45))+BY(7,11)*S(21))+F2*(BX
               (6,1)*S(7)+BX(6,2)*Z(6)+BX(6,3)*Z(15)+BX(6,4)*Z(24)+BX(6,5)*Z(33)+BX(6,
               6)*Z(42)+BX(6,7)*Z(51)+BX(6,8)*Z(60)+BX(6,9)*Z(69)+BX(6,10)*Z(78)+BX(
               6,11)*Z(87)+BX(6,12)*Z(96)+BX(6,13)*Z(105)+BX(6,14)*Z(114)+BX(6,15)*Z(
               123)+BX(6,16)*Z(132)+BX(6,17)*Z(141)+BX(6,18)*Z(150)+BX(6,19)*Z(159)+
               BX(6,20)*S(54))-F3*(AX(6,1)*S(7)+AX(6,2)*Z(6)+AX(6,3)*Z(15)+AX (6,4)
               *Z(24)+AX(6,5)*Z(33)+AX(6,6)*Z(42)+AX(6,7)*Z(51)+AX(6,8)*Z(60)+AX(6,9
               )*Z(69)+AX(6,10)*Z(78)+AX(6,11)*Z(87)+AX(6,12)*Z(96)+AX(6,13)*Z(105)+
               AX(6,14)*Z(114)+AX(6,15)*Z(123)+AX(6,16)*Z(132)+AX(6,17)*Z(141)+AX(6
               ,18)*Z(150)+AX(6,19)*Z(159)+AX(6,20)*S(54))
ZPRIME(43) = F1* (BY(8,1)*S(20)+SUM(BY(8,2:10)*Z(37:45))+BY(8,11)*S(21))+F2*(BX
               (6,1)*S(8)+BX(6,2)*Z(7)+BX(6,3)*Z(16)+BX(6,4)*Z(25)+BX(6,5)*Z(34)+BX(6,
               6)*Z(43)+BX(6,7)*Z(52)+BX(6,8)*Z(61)+BX(6,9)*Z(70)+BX(6,10)*Z(79)+BX(
               6,11)*Z(88)+BX(6,12)*Z(97)+BX(6,13)*Z(106)+BX(6,14)*Z(115)+BX(6,15)*Z(
               124)+BX(6,16)*Z(133)+BX(6,17)*Z(142)+BX(6,18)*Z(151)+BX(6,19)*Z(160)+
               BX(6,20)*S(55))-F3*(AX(6,1)*S(8)+AX(6,2)*Z(7)+AX(6,3)*Z(16)+AX (6,4)
               *Z(25)+AX(6,5)*Z(34)+AX(6,6)*Z(43)+AX(6,7)*Z(52)+AX(6,8)*Z(61)+AX(6,9
               )*Z(70)+AX(6,10)*Z(79)+AX(6,11)*Z(88)+AX(6,12)*Z(97)+AX(6,13)*Z(106)+
               AX(6,14)*Z(115)+AX(6,15)*Z(124)+AX(6,16)*Z(133)+AX(6,17)*Z(142)+AX(6
               ,18)*Z(151)+AX(6,19)*Z(160)+AX(6,20)*S(55))
ZPRIME(44) = F1* (BY(9,1)*S(20)+SUM(BY(9,2:10)*Z(37:45))+BY(9,11)*S(21))+F2*(BX
               (6,1)*S(9)+BX(6,2)*Z(8)+BX(6,3)*Z(17)+BX(6,4)*Z(26)+BX(6,5)*Z(35)+BX(6,
               6)*Z(44)+BX(6,7)*Z(53)+BX(6,8)*Z(62)+BX(6,9)*Z(71)+BX(6,10)*Z(80)+BX(
               6,11)*Z(89)+BX(6,12)*Z(98)+BX(6,13)*Z(107)+BX(6,14)*Z(116)+BX(6,15)*Z(
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             125)+BX(6,16)*Z(134)+BX(6,17)*Z(143)+BX(6,18)*Z(152)+BX(6,19)*Z(161)+
             BX(6,20)*S(56))-F3*(AX(6,1)*S(9)+AX(6,2)*Z(8)+AX(6,3)*Z(17)+AX (6,4)
             *Z(26)+AX(6,5)*Z(35)+AX(6,6)*Z(44)+AX(6,7)*Z(53)+AX(6,8)*Z(62)+AX(6,9
             )*Z(71)+AX(6,10)*Z(80)+AX(6,11)*Z(89)+AX(6,12)*Z(98)+AX(6,13)*Z(107)+
             AX(6,14)*Z(116)+AX(6,15)*Z(125)+AX(6,16)*Z(134)+AX(6,17)*Z(143)+AX(6
             ,18)*Z(152)+AX(6,19)*Z(161)+AX(6,20)*S(56))
ZPRIME(45) = F1* (BY(10,1)*S(20)+SUM(BY(10,2:10)*Z(37:45))+BY(10,11)*S(21))+F2*(BX
             (6,1)*S(10)+BX(6,2)*Z(9)+BX(6,3)*Z(18)+BX(6,4)*Z(27)+BX(6,5)*Z(36)+BX(
             6,6)*Z(45)+BX(6,7)*Z(54)+BX(6,8)*Z(63)+BX(6,9)*Z(72)+BX(6,10)*Z(81)+B
             X(6,11)*Z(90)+BX(6,12)*Z(99)+BX(6,13)*Z(108)+BX(6,14)*Z(117)+BX(6,15)*
             Z(126)+BX(6,16)*Z(135)+BX(6,17)*Z(144)+BX(6,18)*Z(153)+BX(6,19)*Z(162
             )+BX(6,20)*S(57))-F3*(AX(6,1)*S(10)+AX(6,2)*Z(9)+AX(6,3)*Z(18)+AX (6,4)
             *Z(27)+AX(6,5)*Z(36)+AX(6,6)*Z(45)+AX(6,7)*Z(54)+AX(6,8)*Z(63)+AX(6,9
             )*Z(72)+AX(6,10)*Z(81)+AX(6,11)*Z(90)+AX(6,12)*Z(99)+AX(6,13)*Z(108)+
             AX(6,14)*Z(117)+AX(6,15)*Z(126)+AX(6,16)*Z(135)+AX(6,17)*Z(144)+AX(6
             ,18)*Z(153)+AX(6,19)*Z(162)+AX(6,20)*S(57))
ZPRIME(46) = F1* (BY(2,1)*S(22)+SUM(BY(2,2:10)*Z(46:54))+BY(2,11)*S(23))+F2*(BX
             (7,1)*S(2)+BX(7,2)*Z(1)+BX(7,3)*Z(10)+BX(7,4)*Z(19)+BX(7,5)*Z(28)+BX(7,
             6)*Z(37)+BX(7,7)*Z(46)+BX(7,8)*Z(55)+BX(7,9)*Z(64)+BX(7,10)*Z(73)+BX(
             7,11)*Z(82)+BX(7,12)*Z(91)+BX(7,13)*Z(100)+BX(7,14)*Z(109)+BX(7,15)*Z(
             118)+BX(7,16)*Z(127)+BX(7,17)*Z(136)+BX(7,18)*Z(145)+BX(7,19)*Z(154)+
             BX(7,20)*S(49))-F3*(AX(7,1)*S(2)+AX(7,2)*Z(1)+AX(7,3)*Z(10)+AX (7,4)
             *Z(19)+AX(7,5)*Z(28)+AX(7,6)*Z(37)+AX(7,7)*Z(46)+AX(7,8)*Z(55)+AX(7,9
             )*Z(64)+AX(7,10)*Z(73)+AX(7,11)*Z(82)+AX(7,12)*Z(91)+AX(7,13)*Z(100)+
             AX(7,14)*Z(109)+AX(7,15)*Z(118)+AX(7,16)*Z(127)+AX(7,17)*Z(136)+AX(7
             ,18)*Z(145)+AX(7,19)*Z(154)+AX(7,20)*S(49))
ZPRIME(47) = F1* (BY(3,1)*S(22)+SUM(BY(3,2:10)*Z(46:54))+BY(3,11)*S(23))+F2*(BX
             (7,1)*S(3)+BX(7,2)*Z(2)+BX(7,3)*Z(11)+BX(7,4)*Z(20)+BX(7,5)*Z(29)+BX(7,
             6)*Z(38)+BX(7,7)*Z(47)+BX(7,8)*Z(56)+BX(7,9)*Z(65)+BX(7,10)*Z(74)+BX(
             7,11)*Z(83)+BX(7,12)*Z(92)+BX(7,13)*Z(101)+BX(7,14)*Z(110)+BX(7,15)*Z(
             119)+BX(7,16)*Z(128)+BX(7,17)*Z(137)+BX(7,18)*Z(146)+BX(7,19)*Z(155)+
             BX(7,20)*S(50))-F3*(AX(7,1)*S(3)+AX(7,2)*Z(2)+AX(7,3)*Z(11)+AX (7,4)
             *Z(20)+AX(7,5)*Z(29)+AX(7,6)*Z(38)+AX(7,7)*Z(47)+AX(7,8)*Z(56)+AX(7,9
             )*Z(65)+AX(7,10)*Z(74)+AX(7,11)*Z(83)+AX(7,12)*Z(92)+AX(7,13)*Z(101)+
             AX(7,14)*Z(110)+AX(7,15)*Z(119)+AX(7,16)*Z(128)+AX(7,17)*Z(137)+AX(7
             ,18)*Z(146)+AX(7,19)*Z(155)+AX(7,20)*S(50))
ZPRIME(48) = F1* (BY(4,1)*S(22)+SUM(BY(4,2:10)*Z(46:54))+BY(4,11)*S(23))+F2*(BX
             (7,1)*S(4)+BX(7,2)*Z(3)+BX(7,3)*Z(12)+BX(7,4)*Z(21)+BX(7,5)*Z(30)+BX(7,
             6)*Z(39)+BX(7,7)*Z(48)+BX(7,8)*Z(57)+BX(7,9)*Z(66)+BX(7,10)*Z(75)+BX(
             7,11)*Z(84)+BX(7,12)*Z(93)+BX(7,13)*Z(102)+BX(7,14)*Z(111)+BX(7,15)*Z(
             120)+BX(7,16)*Z(129)+BX(7,17)*Z(138)+BX(7,18)*Z(147)+BX(7,19)*Z(156)+
             BX(7,20)*S(51))-F3*(AX(7,1)*S(4)+AX(7,2)*Z(3)+AX(7,3)*Z(12)+AX (7,4)
             *Z(21)+AX(7,5)*Z(30)+AX(7,6)*Z(39)+AX(7,7)*Z(48)+AX(7,8)*Z(57)+AX(7,9
             )*Z(66)+AX(7,10)*Z(75)+AX(7,11)*Z(84)+AX(7,12)*Z(93)+AX(7,13)*Z(102)+
             AX(7,14)*Z(111)+AX(7,15)*Z(120)+AX(7,16)*Z(129)+AX(7,17)*Z(138)+AX(7
             ,18)*Z(147)+AX(7,19)*Z(156)+AX(7,20)*S(51))
ZPRIME(49) = F1* (BY(5,1)*S(22)+SUM(BY(5,2:10)*Z(46:54))+BY(5,11)*S(23))+F2*(BX
             (7,1)*S(5)+BX(7,2)*Z(4)+BX(7,3)*Z(13)+BX(7,4)*Z(22)+BX(7,5)*Z(31)+BX(7,
             6)*Z(40)+BX(7,7)*Z(49)+BX(7,8)*Z(58)+BX(7,9)*Z(67)+BX(7,10)*Z(76)+BX(
             7,11)*Z(85)+BX(7,12)*Z(94)+BX(7,13)*Z(103)+BX(7,14)*Z(112)+BX(7,15)*Z(
             121)+BX(7,16)*Z(130)+BX(7,17)*Z(139)+BX(7,18)*Z(148)+BX(7,19)*Z(157)+
             BX(7,20)*S(52))-F3*(AX(7,1)*S(5)+AX(7,2)*Z(4)+AX(7,3)*Z(13)+AX (7,4)
             *Z(22)+AX(7,5)*Z(31)+AX(7,6)*Z(40)+AX(7,7)*Z(49)+AX(7,8)*Z(58)+AX(7,9
             )*Z(67)+AX(7,10)*Z(76)+AX(7,11)*Z(85)+AX(7,12)*Z(94)+AX(7,13)*Z(103)+
             AX(7,14)*Z(112)+AX(7,15)*Z(121)+AX(7,16)*Z(130)+AX(7,17)*Z(139)+AX(7
             ,18)*Z(148)+AX(7,19)*Z(157)+AX(7,20)*S(52))
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ZPRIME(50) = F1* (BY(6,1)*S(22)+SUM(BY(6,2:10)*Z(46:54))+BY(6,11)*S(23))+F2*(BX
             (7,1)*S(6)+BX(7,2)*Z(5)+BX(7,3)*Z(14)+BX(7,4)*Z(23)+BX(7,5)*Z(32)+BX(7,
             6)*Z(41)+BX(7,7)*Z(50)+BX(7,8)*Z(59)+BX(7,9)*Z(68)+BX(7,10)*Z(77)+BX(
             7,11)*Z(86)+BX(7,12)*Z(95)+BX(7,13)*Z(104)+BX(7,14)*Z(113)+BX(7,15)*Z(
             122)+BX(7,16)*Z(131)+BX(7,17)*Z(140)+BX(7,18)*Z(149)+BX(7,19)*Z(158)+
             BX(7,20)*S(53))-F3*(AX(7,1)*S(6)+AX(7,2)*Z(5)+AX(7,3)*Z(14)+AX (7,4)
             *Z(23)+AX(7,5)*Z(32)+AX(7,6)*Z(41)+AX(7,7)*Z(50)+AX(7,8)*Z(59)+AX(7,9
             )*Z(68)+AX(7,10)*Z(77)+AX(7,11)*Z(86)+AX(7,12)*Z(95)+AX(7,13)*Z(104)+
             AX(7,14)*Z(113)+AX(7,15)*Z(122)+AX(7,16)*Z(131)+AX(7,17)*Z(140)+AX(7
             ,18)*Z(149)+AX(7,19)*Z(158)+AX(7,20)*S(53))
ZPRIME(51) = F1* (BY(7,1)*S(22)+SUM(BY(7,2:10)*Z(46:54))+BY(7,11)*S(23))+F2*(BX
             (7,1)*S(7)+BX(7,2)*Z(6)+BX(7,3)*Z(15)+BX(7,4)*Z(24)+BX(7,5)*Z(33)+BX(7,
             6)*Z(42)+BX(7,7)*Z(51)+BX(7,8)*Z(60)+BX(7,9)*Z(69)+BX(7,10)*Z(78)+BX(
             7,11)*Z(87)+BX(7,12)*Z(96)+BX(7,13)*Z(105)+BX(7,14)*Z(114)+BX(7,15)*Z(
             123)+BX(7,16)*Z(132)+BX(7,17)*Z(141)+BX(7,18)*Z(150)+BX(7,19)*Z(159)+
             BX(7,20)*S(54))-F3*(AX(7,1)*S(7)+AX(7,2)*Z(6)+AX(7,3)*Z(15)+AX (7,4)
             *Z(24)+AX(7,5)*Z(33)+AX(7,6)*Z(42)+AX(7,7)*Z(51)+AX(7,8)*Z(60)+AX(7,9
             )*Z(69)+AX(7,10)*Z(78)+AX(7,11)*Z(87)+AX(7,12)*Z(96)+AX(7,13)*Z(105)+
             AX(7,14)*Z(114)+AX(7,15)*Z(123)+AX(7,16)*Z(132)+AX(7,17)*Z(141)+AX(7
             ,18)*Z(150)+AX(7,19)*Z(159)+AX(7,20)*S(54))
ZPRIME(52) = F1* (BY(8,1)*S(22)+SUM(BY(8,2:10)*Z(46:54))+BY(8,11)*S(23))+F2*(BX
             (7,1)*S(8)+BX(7,2)*Z(7)+BX(7,3)*Z(16)+BX(7,4)*Z(25)+BX(7,5)*Z(34)+BX(7,
             6)*Z(43)+BX(7,7)*Z(52)+BX(7,8)*Z(61)+BX(7,9)*Z(70)+BX(7,10)*Z(79)+BX(
             7,11)*Z(88)+BX(7,12)*Z(97)+BX(7,13)*Z(106)+BX(7,14)*Z(115)+BX(7,15)*Z(
             124)+BX(7,16)*Z(133)+BX(7,17)*Z(142)+BX(7,18)*Z(151)+BX(7,19)*Z(160)+
             BX(7,20)*S(55))-F3*(AX(7,1)*S(8)+AX(7,2)*Z(7)+AX(7,3)*Z(16)+AX (7,4)
             *Z(25)+AX(7,5)*Z(34)+AX(7,6)*Z(43)+AX(7,7)*Z(52)+AX(7,8)*Z(61)+AX(7,9
             )*Z(70)+AX(7,10)*Z(79)+AX(7,11)*Z(88)+AX(7,12)*Z(97)+AX(7,13)*Z(106)+
             AX(7,14)*Z(115)+AX(7,15)*Z(124)+AX(7,16)*Z(133)+AX(7,17)*Z(142)+AX(7
             ,18)*Z(151)+AX(7,19)*Z(160)+AX(7,20)*S(55))
ZPRIME(53) = F1* (BY(9,1)*S(22)+SUM(BY(9,2:10)*Z(46:54))+BY(9,11)*S(23))+F2*(BX
             (7,1)*S(9)+BX(7,2)*Z(8)+BX(7,3)*Z(17)+BX(7,4)*Z(26)+BX(7,5)*Z(35)+BX(7,
             6)*Z(44)+BX(7,7)*Z(53)+BX(7,8)*Z(62)+BX(7,9)*Z(71)+BX(7,10)*Z(80)+BX(
             7,11)*Z(89)+BX(7,12)*Z(98)+BX(7,13)*Z(107)+BX(7,14)*Z(116)+BX(7,15)*Z(
             125)+BX(7,16)*Z(134)+BX(7,17)*Z(143)+BX(7,18)*Z(152)+BX(7,19)*Z(161)+
             BX(7,20)*S(56))-F3*(AX(7,1)*S(9)+AX(7,2)*Z(8)+AX(7,3)*Z(17)+AX (7,4)
             *Z(26)+AX(7,5)*Z(35)+AX(7,6)*Z(44)+AX(7,7)*Z(53)+AX(7,8)*Z(62)+AX(7,9
             )*Z(71)+AX(7,10)*Z(80)+AX(7,11)*Z(89)+AX(7,12)*Z(98)+AX(7,13)*Z(107)+
             AX(7,14)*Z(116)+AX(7,15)*Z(125)+AX(7,16)*Z(134)+AX(7,17)*Z(143)+AX(7
             ,18)*Z(152)+AX(7,19)*Z(161)+AX(7,20)*S(56))
ZPRIME(54) = F1*(BY(10,1)*S(22)+SUM(BY(10,2:10)*Z(46:54))+BY(10,11)*S(23))+F2*(BX
             (7,1)*S(10)+BX(7,2)*Z(9)+BX(7,3)*Z(18)+BX(7,4)*Z(27)+BX(7,5)*Z(36)+BX(
             7,6)*Z(45)+BX(7,7)*Z(54)+BX(7,8)*Z(63)+BX(7,9)*Z(72)+BX(7,10)*Z(81)+B
             X(7,11)*Z(90)+BX(7,12)*Z(99)+BX(7,13)*Z(108)+BX(7,14)*Z(117)+BX(7,15)*
             Z(126)+BX(7,16)*Z(135)+BX(7,17)*Z(144)+BX(7,18)*Z(153)+BX(7,19)*Z(162
             )+BX(7,20)*S(57))-F3*(AX(7,1)*S(10)+AX(7,2)*Z(9)+AX(7,3)*Z(18)+AX (7,4)
             *Z(27)+AX(7,5)*Z(36)+AX(7,6)*Z(45)+AX(7,7)*Z(54)+AX(7,8)*Z(63)+AX(7,9
             )*Z(72)+AX(7,10)*Z(81)+AX(7,11)*Z(90)+AX(7,12)*Z(99)+AX(7,13)*Z(108)+
             AX(7,14)*Z(117)+AX(7,15)*Z(126)+AX(7,16)*Z(135)+AX(7,17)*Z(144)+AX(7
             ,18)*Z(153)+AX(7,19)*Z(162)+AX(7,20)*S(57))
ZPRIME(55) = F1* (BY(2,1)*S(24)+SUM(BY(2,2:10)*Z(55:63))+BY(2,11)*S(25))+F2*(BX
             (8,1)*S(2)+BX(8,2)*Z(1)+BX(8,3)*Z(10)+BX(8,4)*Z(19)+BX(8,5)*Z(28)+BX(8,
             6)*Z(37)+BX(8,7)*Z(46)+BX(8,8)*Z(55)+BX(8,9)*Z(64)+BX(8,10)*Z(73)+BX(
             8,11)*Z(82)+BX(8,12)*Z(91)+BX(8,13)*Z(100)+BX(8,14)*Z(109)+BX(8,15)*Z(
             118)+BX(8,16)*Z(127)+BX(8,17)*Z(136)+BX(8,18)*Z(145)+BX(8,19)*Z(154)+
             BX(8,20)*S(49))-F3*(AX(8,1)*S(2)+AX(8,2)*Z(1)+AX(8,3)*Z(10)+AX (8,4)
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*Z(19)+AX(8,5)*Z(28)+AX(8,6)*Z(37)+AX(8,7)*Z(46)+AX(8,8)*Z(55)+AX(8,9
)*Z(64)+AX(8,10)*Z(73)+AX(8,11)*Z(82)+AX(8,12)*Z(91)+AX(8,13)*Z(100)+
AX(8,14)*Z(109)+AX(8,15)*Z(118)+AX(8,16)*Z(127)+AX(8,17)*Z(136)+AX(8
,18)*Z(145)+AX(8,19)*Z(154)+AX(8,20)*S(49))
ZPRIME(56) = F1* (BY(3,1)*S(24)+SUM(BY(3,2:10)*Z(55:63))+BY(3,11)*S(25))+F2*(BX
(8,1)*S(3)+BX(8,2)*Z(2)+BX(8,3)*Z(11)+BX(8,4)*Z(20)+BX(8,5)*Z(29)+BX(8,
6)*Z(38)+BX(8,7)*Z(47)+BX(8,8)*Z(56)+BX(8,9)*Z(65)+BX(8,10)*Z(74)+BX(
8,11)*Z(83)+BX(8,12)*Z(92)+BX(8,13)*Z(101)+BX(8,14)*Z(110)+BX(8,15)*Z(
119)+BX(8,16)*Z(128)+BX(8,17)*Z(137)+BX(8,18)*Z(146)+BX(8,19)*Z(155)+
BX(8,20)*S(50))-F3*(AX(8,1)*S(3)+AX(8,2)*Z(2)+AX(8,3)*Z(11)+AX (8,4)
*Z(20)+AX(8,5)*Z(29)+AX(8,6)*Z(38)+AX(8,7)*Z(47)+AX(8,8)*Z(56)+AX(8,9
)*Z(65)+AX(8,10)*Z(74)+AX(8,11)*Z(83)+AX(8,12)*Z(92)+AX(8,13)*Z(101)+
AX(8,14)*Z(110)+AX(8,15)*Z(119)+AX(8,16)*Z(128)+AX(8,17)*Z(137)+AX(8
,18)*Z(146)+AX(8,19)*Z(155)+AX(8,20)*S(50))
ZPRIME(57) = F1* (BY(4,1)*S(24)+SUM(BY(4,2:10)*Z(55:63))+BY(4,11)*S(25))+F2*(BX
(8,1)*S(4)+BX(8,2)*Z(3)+BX(8,3)*Z(12)+BX(8,4)*Z(21)+BX(8,5)*Z(30)+BX(8,
6)*Z(39)+BX(8,7)*Z(48)+BX(8,8)*Z(57)+BX(8,9)*Z(66)+BX(8,10)*Z(75)+BX(
8,11)*Z(84)+BX(8,12)*Z(93)+BX(8,13)*Z(102)+BX(8,14)*Z(111)+BX(8,15)*Z(
120)+BX(8,16)*Z(129)+BX(8,17)*Z(138)+BX(8,18)*Z(147)+BX(8,19)*Z(156)+
BX(8,20)*S(51))-F3*(AX(8,1)*S(4)+AX(8,2)*Z(3)+AX(8,3)*Z(12)+AX (8,4)
*Z(21)+AX(8,5)*Z(30)+AX(8,6)*Z(39)+AX(8,7)*Z(48)+AX(8,8)*Z(57)+AX(8,9
)*Z(66)+AX(8,10)*Z(75)+AX(8,11)*Z(84)+AX(8,12)*Z(93)+AX(8,13)*Z(102)+
AX(8,14)*Z(111)+AX(8,15)*Z(120)+AX(8,16)*Z(129)+AX(8,17)*Z(138)+AX(8
,18)*Z(147)+AX(8,19)*Z(156)+AX(8,20)*S(51))
ZPRIME(58) = F1* (BY(5,1)*S(24)+SUM(BY(5,2:10)*Z(55:63))+BY(5,11)*S(25))+F2*(BX
(8,1)*S(5)+BX(8,2)*Z(4)+BX(8,3)*Z(13)+BX(8,4)*Z(22)+BX(8,5)*Z(31)+BX(8,
6)*Z(40)+BX(8,7)*Z(49)+BX(8,8)*Z(58)+BX(8,9)*Z(67)+BX(8,10)*Z(76)+BX(
8,11)*Z(85)+BX(8,12)*Z(94)+BX(8,13)*Z(103)+BX(8,14)*Z(112)+BX(8,15)*Z(
121)+BX(8,16)*Z(130)+BX(8,17)*Z(139)+BX(8,18)*Z(148)+BX(8,19)*Z(157)+
BX(8,20)*S(52))-F3*(AX(8,1)*S(5)+AX(8,2)*Z(4)+AX(8,3)*Z(13)+AX (8,4)
*Z(22)+AX(8,5)*Z(31)+AX(8,6)*Z(40)+AX(8,7)*Z(49)+AX(8,8)*Z(58)+AX(8,9
)*Z(67)+AX(8,10)*Z(76)+AX(8,11)*Z(85)+AX(8,12)*Z(94)+AX(8,13)*Z(103)+
AX(8,14)*Z(112)+AX(8,15)*Z(121)+AX(8,16)*Z(130)+AX(8,17)*Z(139)+AX(8
,18)*Z(148)+AX(8,19)*Z(157)+AX(8,20)*S(52))
ZPRIME(59) = F1* (BY(6,1)*S(24)+SUM(BY(6,2:10)*Z(55:63))+BY(6,11)*S(25))+F2*(BX
(8,1)*S(6)+BX(8,2)*Z(5)+BX(8,3)*Z(14)+BX(8,4)*Z(23)+BX(8,5)*Z(32)+BX(8,
6)*Z(41)+BX(8,7)*Z(50)+BX(8,8)*Z(59)+BX(8,9)*Z(68)+BX(8,10)*Z(77)+BX(
8,11)*Z(86)+BX(8,12)*Z(95)+BX(8,13)*Z(104)+BX(8,14)*Z(113)+BX(8,15)*Z(
122)+BX(8,16)*Z(131)+BX(8,17)*Z(140)+BX(8,18)*Z(149)+BX(8,19)*Z(158)+
BX(8,20)*S(53))-F3*(AX(8,1)*S(6)+AX(8,2)*Z(5)+AX(8,3)*Z(14)+AX (8,4)
*Z(23)+AX(8,5)*Z(32)+AX(8,6)*Z(41)+AX(8,7)*Z(50)+AX(8,8)*Z(59)+AX(8,9
)*Z(68)+AX(8,10)*Z(77)+AX(8,11)*Z(86)+AX(8,12)*Z(95)+AX(8,13)*Z(104)+
AX(8,14)*Z(113)+AX(8,15)*Z(122)+AX(8,16)*Z(131)+AX(8,17)*Z(140)+AX(8
,18)*Z(149)+AX(8,19)*Z(158)+AX(8,20)*S(53))
ZPRIME(60) = F1* (BY(7,1)*S(24)+SUM(BY(7,2:10)*Z(55:63))+BY(7,11)*S(25))+F2*(BX
(8,1)*S(7)+BX(8,2)*Z(6)+BX(8,3)*Z(15)+BX(8,4)*Z(24)+BX(8,5)*Z(33)+BX(8,
6)*Z(42)+BX(8,7)*Z(51)+BX(8,8)*Z(60)+BX(8,9)*Z(69)+BX(8,10)*Z(78)+BX(
8,11)*Z(87)+BX(8,12)*Z(96)+BX(8,13)*Z(105)+BX(8,14)*Z(114)+BX(8,15)*Z(
123)+BX(8,16)*Z(132)+BX(8,17)*Z(141)+BX(8,18)*Z(150)+BX(8,19)*Z(159)+
BX(8,20)*S(54))-F3*(AX(8,1)*S(7)+AX(8,2)*Z(6)+AX(8,3)*Z(15)+AX (8,4)
*Z(24)+AX(8,5)*Z(33)+AX(8,6)*Z(42)+AX(8,7)*Z(51)+AX(8,8)*Z(60)+AX(8,9
)*Z(69)+AX(8,10)*Z(78)+AX(8,11)*Z(87)+AX(8,12)*Z(96)+AX(8,13)*Z(105)+
AX(8,14)*Z(114)+AX(8,15)*Z(123)+AX(8,16)*Z(132)+AX(8,17)*Z(141)+AX(8
,18)*Z(150)+AX(8,19)*Z(159)+AX(8,20)*S(54))
ZPRIME(61) = F1* (BY(8,1)*S(24)+SUM(BY(8,2:10)*Z(55:63))+BY(8,11)*S(25))+F2*(BX
(8,1)*S(8)+BX(8,2)*Z(7)+BX(8,3)*Z(16)+BX(8,4)*Z(25)+BX(8,5)*Z(34)+BX(8,
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                6)*Z(43)+BX(8,7)*Z(52)+BX(8,8)*Z(61)+BX(8,9)*Z(70)+BX(8,10)*Z(79)+BX(
                8,11)*Z(88)+BX(8,12)*Z(97)+BX(8,13)*Z(106)+BX(8,14)*Z(115)+BX(8,15)*Z(
                124)+BX(8,16)*Z(133)+BX(8,17)*Z(142)+BX(8,18)*Z(151)+BX(8,19)*Z(160)+
                BX(8,20)*S(55))-F3*(AX(8,1)*S(8)+AX(8,2)*Z(7)+AX(8,3)*Z(16)+AX (8,4)
                *Z(25)+AX(8,5)*Z(34)+AX(8,6)*Z(43)+AX(8,7)*Z(52)+AX(8,8)*Z(61)+AX(8,9
                )*Z(70)+AX(8,10)*Z(79)+AX(8,11)*Z(88)+AX(8,12)*Z(97)+AX(8,13)*Z(106)+
                AX(8,14)*Z(115)+AX(8,15)*Z(124)+AX(8,16)*Z(133)+AX(8,17)*Z(142)+AX(8
                ,18)*Z(151)+AX(8,19)*Z(160)+AX(8,20)*S(55))
ZPRIME(62) = F1* (BY(9,1)*S(24)+SUM(BY(9,2:10)*Z(55:63))+BY(9,11)*S(25))+F2*(BX
                (8,1)*S(9)+BX(8,2)*Z(8)+BX(8,3)*Z(17)+BX(8,4)*Z(26)+BX(8,5)*Z(35)+BX(8,
                6)*Z(44)+BX(8,7)*Z(53)+BX(8,8)*Z(62)+BX(8,9)*Z(71)+BX(8,10)*Z(80)+BX(
                8,11)*Z(89)+BX(8,12)*Z(98)+BX(8,13)*Z(107)+BX(8,14)*Z(116)+BX(8,15)*Z(
                125)+BX(8,16)*Z(134)+BX(8,17)*Z(143)+BX(8,18)*Z(152)+BX(8,19)*Z(161)+
                BX(8,20)*S(56))-F3*(AX(8,1)*S(9)+AX(8,2)*Z(8)+AX(8,3)*Z(17)+AX (8,4)
                *Z(26)+AX(8,5)*Z(35)+AX(8,6)*Z(44)+AX(8,7)*Z(53)+AX(8,8)*Z(62)+AX(8,9
                )*Z(71)+AX(8,10)*Z(80)+AX(8,11)*Z(89)+AX(8,12)*Z(98)+AX(8,13)*Z(107)+
                AX(8,14)*Z(116)+AX(8,15)*Z(125)+AX(8,16)*Z(134)+AX(8,17)*Z(143)+AX(8
                ,18)*Z(152)+AX(8,19)*Z(161)+AX(8,20)*S(56))
ZPRIME(63) = F1*(BY(10,1)*S(24)+SUM(BY(10,2:10)*Z(55:63))+BY(10,11)*S(25))+F2*(BX
                (8,1)*S(10)+BX(8,2)*Z(9)+BX(8,3)*Z(18)+BX(8,4)*Z(27)+BX(8,5)*Z(36)+BX(
                8,6)*Z(45)+BX(8,7)*Z(54)+BX(8,8)*Z(63)+BX(8,9)*Z(72)+BX(8,10)*Z(81)+B
                X(8,11)*Z(90)+BX(8,12)*Z(99)+BX(8,13)*Z(108)+BX(8,14)*Z(117)+BX(8,15)*
                Z(126)+BX(8,16)*Z(135)+BX(8,17)*Z(144)+BX(8,18)*Z(153)+BX(8,19)*Z(162
                )+BX(8,20)*S(57))-F3*(AX(8,1)*S(10)+AX(8,2)*Z(9)+AX(8,3)*Z(18)+AX (8,4)
                *Z(27)+AX(8,5)*Z(36)+AX(8,6)*Z(45)+AX(8,7)*Z(54)+AX(8,8)*Z(63)+AX(8,9
                )*Z(72)+AX(8,10)*Z(81)+AX(8,11)*Z(90)+AX(8,12)*Z(99)+AX(8,13)*Z(108)+
                AX(8,14)*Z(117)+AX(8,15)*Z(126)+AX(8,16)*Z(135)+AX(8,17)*Z(144)+AX(8
                ,18)*Z(153)+AX(8,19)*Z(162)+AX(8,20)*S(57))
ZPRIME(64) = F1* (BY(2,1)*S(26)+SUM(BY(2,2:10)*Z(64:72))+BY(2,11)*S(27))+F2*(BX
                (9,1)*S(2)+BX(9,2)*Z(1)+BX(9,3)*Z(10)+BX(9,4)*Z(19)+BX(9,5)*Z(28)+BX(9,
                6)*Z(37)+BX(9,7)*Z(46)+BX(9,8)*Z(55)+BX(9,9)*Z(64)+BX(9,10)*Z(73)+BX(
                9,11)*Z(82)+BX(9,12)*Z(91)+BX(9,13)*Z(100)+BX(9,14)*Z(109)+BX(9,15)*Z(
                118)+BX(9,16)*Z(127)+BX(9,17)*Z(136)+BX(9,18)*Z(145)+BX(9,19)*Z(154)+
                BX(9,20)*S(49))-F3*(AX(9,1)*S(2)+AX(9,2)*Z(1)+AX(9,3)*Z(10)+AX (9,4)
                *Z(19)+AX(9,5)*Z(28)+AX(9,6)*Z(37)+AX(9,7)*Z(46)+AX(9,8)*Z(55)+AX(9,9
                )*Z(64)+AX(9,10)*Z(73)+AX(9,11)*Z(82)+AX(9,12)*Z(91)+AX(9,13)*Z(100)+
                AX(9,14)*Z(109)+AX(9,15)*Z(118)+AX(9,16)*Z(127)+AX(9,17)*Z(136)+AX(9
                ,18)*Z(145)+AX(9,19)*Z(154)+AX(9,20)*S(49))
ZPRIME(65) = F1* (BY(3,1)*S(26)+SUM(BY(3,2:10)*Z(64:72))+BY(3,11)*S(27))+F2*(BX
                (9,1)*S(3)+BX(9,2)*Z(2)+BX(9,3)*Z(11)+BX(9,4)*Z(20)+BX(9,5)*Z(29)+BX(9,
                6)*Z(38)+BX(9,7)*Z(47)+BX(9,8)*Z(56)+BX(9,9)*Z(65)+BX(9,10)*Z(74)+BX(
                9,11)*Z(83)+BX(9,12)*Z(92)+BX(9,13)*Z(101)+BX(9,14)*Z(110)+BX(9,15)*Z(
                119)+BX(9,16)*Z(128)+BX(9,17)*Z(137)+BX(9,18)*Z(146)+BX(9,19)*Z(155)+
                BX(9,20)*S(50))-F3*(AX(9,1)*S(3)+AX(9,2)*Z(2)+AX(9,3)*Z(11)+AX (9,4)
                *Z(20)+AX(9,5)*Z(29)+AX(9,6)*Z(38)+AX(9,7)*Z(47)+AX(9,8)*Z(56)+AX(9,9
                )*Z(65)+AX(9,10)*Z(74)+AX(9,11)*Z(83)+AX(9,12)*Z(92)+AX(9,13)*Z(101)+
                AX(9,14)*Z(110)+AX(9,15)*Z(119)+AX(9,16)*Z(128)+AX(9,17)*Z(137)+AX(9
                ,18)*Z(146)+AX(9,19)*Z(155)+AX(9,20)*S(50))
ZPRIME(66) = F1* (BY(4,1)*S(26)+SUM(BY(4,2:10)*Z(64:72))+BY(4,11)*S(27))+F2*(BX
                (9,1)*S(4)+BX(9,2)*Z(3)+BX(9,3)*Z(12)+BX(9,4)*Z(21)+BX(9,5)*Z(30)+BX(9,
                6)*Z(39)+BX(9,7)*Z(48)+BX(9,8)*Z(57)+BX(9,9)*Z(66)+BX(9,10)*Z(75)+BX(
                9,11)*Z(84)+BX(9,12)*Z(93)+BX(9,13)*Z(102)+BX(9,14)*Z(111)+BX(9,15)*Z(
                120)+BX(9,16)*Z(129)+BX(9,17)*Z(138)+BX(9,18)*Z(147)+BX(9,19)*Z(156)+
                BX(9,20)*S(51))-F3*(AX(9,1)*S(4)+AX(9,2)*Z(3)+AX(9,3)*Z(12)+AX (9,4)
                *Z(21)+AX(9,5)*Z(30)+AX(9,6)*Z(39)+AX(9,7)*Z(48)+AX(9,8)*Z(57)+AX(9,9
                )*Z(66)+AX(9,10)*Z(75)+AX(9,11)*Z(84)+AX(9,12)*Z(93)+AX(9,13)*Z(102)+
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                AX(9,14)*Z(111)+AX(9,15)*Z(120)+AX(9,16)*Z(129)+AX(9,17)*Z(138)+AX(9
                ,18)*Z(147)+AX(9,19)*Z(156)+AX(9,20)*S(51))
ZPRIME(67) = F1* (BY(5,1)*S(26)+SUM(BY(5,2:10)*Z(64:72))+BY(5,11)*S(27))+F2*(BX
                (9,1)*S(5)+BX(9,2)*Z(4)+BX(9,3)*Z(13)+BX(9,4)*Z(22)+BX(9,5)*Z(31)+BX(9,
                6)*Z(40)+BX(9,7)*Z(49)+BX(9,8)*Z(58)+BX(9,9)*Z(67)+BX(9,10)*Z(76)+BX(
                9,11)*Z(85)+BX(9,12)*Z(94)+BX(9,13)*Z(103)+BX(9,14)*Z(112)+BX(9,15)*Z(
                121)+BX(9,16)*Z(130)+BX(9,17)*Z(139)+BX(9,18)*Z(148)+BX(9,19)*Z(157)+
                BX(9,20)*S(52))-F3*(AX(9,1)*S(5)+AX(9,2)*Z(4)+AX(9,3)*Z(13)+AX (9,4)
                *Z(22)+AX(9,5)*Z(31)+AX(9,6)*Z(40)+AX(9,7)*Z(49)+AX(9,8)*Z(58)+AX(9,9
                )*Z(67)+AX(9,10)*Z(76)+AX(9,11)*Z(85)+AX(9,12)*Z(94)+AX(9,13)*Z(103)+
                AX(9,14)*Z(112)+AX(9,15)*Z(121)+AX(9,16)*Z(130)+AX(9,17)*Z(139)+AX(9
                ,18)*Z(148)+AX(9,19)*Z(157)+AX(9,20)*S(52))
ZPRIME(68) = F1* (BY(6,1)*S(26)+SUM(BY(6,2:10)*Z(64:72))+BY(6,11)*S(27))+F2*(BX
                (9,1)*S(6)+BX(9,2)*Z(5)+BX(9,3)*Z(14)+BX(9,4)*Z(23)+BX(9,5)*Z(32)+BX(9,
                6)*Z(41)+BX(9,7)*Z(50)+BX(9,8)*Z(59)+BX(9,9)*Z(68)+BX(9,10)*Z(77)+BX(
                9,11)*Z(86)+BX(9,12)*Z(95)+BX(9,13)*Z(104)+BX(9,14)*Z(113)+BX(9,15)*Z(
                122)+BX(9,16)*Z(131)+BX(9,17)*Z(140)+BX(9,18)*Z(149)+BX(9,19)*Z(158)+
                BX(9,20)*S(53))-F3*(AX(9,1)*S(6)+AX(9,2)*Z(5)+AX(9,3)*Z(14)+AX (9,4)
                *Z(23)+AX(9,5)*Z(32)+AX(9,6)*Z(41)+AX(9,7)*Z(50)+AX(9,8)*Z(59)+AX(9,9
                )*Z(68)+AX(9,10)*Z(77)+AX(9,11)*Z(86)+AX(9,12)*Z(95)+AX(9,13)*Z(104)+
                AX(9,14)*Z(113)+AX(9,15)*Z(122)+AX(9,16)*Z(131)+AX(9,17)*Z(140)+AX(9
                ,18)*Z(149)+AX(9,19)*Z(158)+AX(9,20)*S(53))
ZPRIME(69) = F1* (BY(7,1)*S(26)+SUM(BY(7,2:10)*Z(64:72))+BY(7,11)*S(27))+F2*(BX
                (9,1)*S(7)+BX(9,2)*Z(6)+BX(9,3)*Z(15)+BX(9,4)*Z(24)+BX(9,5)*Z(33)+BX(9,
                6)*Z(42)+BX(9,7)*Z(51)+BX(9,8)*Z(60)+BX(9,9)*Z(69)+BX(9,10)*Z(78)+BX(
                9,11)*Z(87)+BX(9,12)*Z(96)+BX(9,13)*Z(105)+BX(9,14)*Z(114)+BX(9,15)*Z(
                123)+BX(9,16)*Z(132)+BX(9,17)*Z(141)+BX(9,18)*Z(150)+BX(9,19)*Z(159)+
                BX(9,20)*S(54))-F3*(AX(9,1)*S(7)+AX(9,2)*Z(6)+AX(9,3)*Z(15)+AX (9,4)
                *Z(24)+AX(9,5)*Z(33)+AX(9,6)*Z(42)+AX(9,7)*Z(51)+AX(9,8)*Z(60)+AX(9,9
                )*Z(69)+AX(9,10)*Z(78)+AX(9,11)*Z(87)+AX(9,12)*Z(96)+AX(9,13)*Z(105)+
                AX(9,14)*Z(114)+AX(9,15)*Z(123)+AX(9,16)*Z(132)+AX(9,17)*Z(141)+AX(9
                ,18)*Z(150)+AX(9,19)*Z(159)+AX(9,20)*S(54))
ZPRIME(70) = F1* (BY(8,1)*S(26)+SUM(BY(8,2:10)*Z(64:72))+BY(8,11)*S(27))+F2*(BX
                (9,1)*S(8)+BX(9,2)*Z(7)+BX(9,3)*Z(16)+BX(9,4)*Z(25)+BX(9,5)*Z(34)+BX(9,
                6)*Z(43)+BX(9,7)*Z(52)+BX(9,8)*Z(61)+BX(9,9)*Z(70)+BX(9,10)*Z(79)+BX(
                9,11)*Z(88)+BX(9,12)*Z(97)+BX(9,13)*Z(106)+BX(9,14)*Z(115)+BX(9,15)*Z(
                124)+BX(9,16)*Z(133)+BX(9,17)*Z(142)+BX(9,18)*Z(151)+BX(9,19)*Z(160)+
                BX(9,20)*S(55))-F3*(AX(9,1)*S(8)+AX(9,2)*Z(7)+AX(9,3)*Z(16)+AX (9,4)
                *Z(25)+AX(9,5)*Z(34)+AX(9,6)*Z(43)+AX(9,7)*Z(52)+AX(9,8)*Z(61)+AX(9,9
                )*Z(70)+AX(9,10)*Z(79)+AX(9,11)*Z(88)+AX(9,12)*Z(97)+AX(9,13)*Z(106)+
                AX(9,14)*Z(115)+AX(9,15)*Z(124)+AX(9,16)*Z(133)+AX(9,17)*Z(142)+AX(9
                ,18)*Z(151)+AX(9,19)*Z(160)+AX(9,20)*S(55))
ZPRIME(71) = F1* (BY(9,1)*S(26)+SUM(BY(9,2:10)*Z(64:72))+BY(9,11)*S(27))+F2*(BX
                (9,1)*S(9)+BX(9,2)*Z(8)+BX(9,3)*Z(17)+BX(9,4)*Z(26)+BX(9,5)*Z(35)+BX(9,
                6)*Z(44)+BX(9,7)*Z(53)+BX(9,8)*Z(62)+BX(9,9)*Z(71)+BX(9,10)*Z(80)+BX(
                9,11)*Z(89)+BX(9,12)*Z(98)+BX(9,13)*Z(107)+BX(9,14)*Z(116)+BX(9,15)*Z(
                125)+BX(9,16)*Z(134)+BX(9,17)*Z(143)+BX(9,18)*Z(152)+BX(9,19)*Z(161)+
                BX(9,20)*S(56))-F3*(AX(9,1)*S(9)+AX(9,2)*Z(8)+AX(9,3)*Z(17)+AX (9,4)
                *Z(26)+AX(9,5)*Z(35)+AX(9,6)*Z(44)+AX(9,7)*Z(53)+AX(9,8)*Z(62)+AX(9,9
                )*Z(71)+AX(9,10)*Z(80)+AX(9,11)*Z(89)+AX(9,12)*Z(98)+AX(9,13)*Z(107)+
                AX(9,14)*Z(116)+AX(9,15)*Z(125)+AX(9,16)*Z(134)+AX(9,17)*Z(143)+AX(9
                ,18)*Z(152)+AX(9,19)*Z(161)+AX(9,20)*S(56))
ZPRIME(72) = F1*(BY(10,1)*S(26)+SUM(BY(10,2:10)*Z(64:72))+BY(10,11)*S(27))+F2*(BX
                (9,1)*S(10)+BX(9,2)*Z(9)+BX(9,3)*Z(18)+BX(9,4)*Z(27)+BX(9,5)*Z(36)+BX(
                9,6)*Z(45)+BX(9,7)*Z(54)+BX(9,8)*Z(63)+BX(9,9)*Z(72)+BX(9,10)*Z(81)+B
                X(9,11)*Z(90)+BX(9,12)*Z(99)+BX(9,13)*Z(108)+BX(9,14)*Z(117)+BX(9,15)*
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Z(126)+BX(9,16)*Z(135)+BX(9,17)*Z(144)+BX(9,18)*Z(153)+BX(9,19)*Z(162
)+BX(9,20)*S(57))-F3*(AX(9,1)*S(10)+AX(9,2)*Z(9)+AX(9,3)*Z(18)+AX (9,4)
*Z(27)+AX(9,5)*Z(36)+AX(9,6)*Z(45)+AX(9,7)*Z(54)+AX(9,8)*Z(63)+AX(9,9
)*Z(72)+AX(9,10)*Z(81)+AX(9,11)*Z(90)+AX(9,12)*Z(99)+AX(9,13)*Z(108)+
AX(9,14)*Z(117)+AX(9,15)*Z(126)+AX(9,16)*Z(135)+AX(9,17)*Z(144)+AX(9
,18)*Z(153)+AX(9,19)*Z(162)+AX(9,20)*S(57))
ZPRIME(73) = F1* (BY(2,1)*S(28)+SUM(BY(2,2:10)*Z(73:81))+BY(2,11)*S(29))+F2*(BX
(10,1)*S(2)+BX(10,2)*Z(1)+BX(10,3)*Z(10)+BX(10,4)*Z(19)+BX(10,5)*Z(28)+
BX(10,6)*Z(37)+BX(10,7)*Z(46)+BX(10,8)*Z(55)+BX(10,9)*Z(64)+BX(10,10)
*Z(73)+BX(10,11)*Z(82)+BX(10,12)*Z(91)+BX(10,13)*Z(100)+BX(10,14)*Z(1
09)+BX(10,15)*Z(118)+BX(10,16)*Z(127)+BX(10,17)*Z(136)+BX(10,18)*Z(14
5)+BX(10,19)*Z(154)+BX(10,20)*S(49))-F3*(AX(10,1)*S(2)+AX(10,2)* Z(1)+
AX(10,3)*Z(10)+AX(10,4)*Z(19)+AX(10,5)*Z(28)+AX(10,6)*Z(37)+AX(10,7)*
Z(46)+AX(10,8)*Z(55)+AX(10,9)*Z(64)+AX(10,10)*Z(73)+AX(10,11)*Z(82)+
AX(10,12)*Z(91)+AX(10,13)*Z(100)+AX(10,14)*Z(109)+AX(10,15)*Z(118)+A
X(10,16)*Z(127)+AX(10,17)*Z(136)+AX(10,18)*Z(145)+AX(10,19)*Z(154)+A
X(10,20)*S(49))
ZPRIME(74) = F1* (BY(3,1)*S(28)+SUM(BY(3,2:10)*Z(73:81))+BY(3,11)*S(29))+F2*(BX
(10,1)*S(3)+BX(10,2)*Z(2)+BX(10,3)*Z(11)+BX(10,4)*Z(20)+BX(10,5)*Z(29)+
BX(10,6)*Z(38)+BX(10,7)*Z(47)+BX(10,8)*Z(56)+BX(10,9)*Z(65)+BX(10,10)
*Z(74)+BX(10,11)*Z(83)+BX(10,12)*Z(92)+BX(10,13)*Z(101)+BX(10,14)*Z(1
10)+BX(10,15)*Z(119)+BX(10,16)*Z(128)+BX(10,17)*Z(137)+BX(10,18)*Z(14
6)+BX(10,19)*Z(155)+BX(10,20)*S(50))-F3*(AX(10,1)*S(3)+AX(10,2)* Z(2)+
AX(10,3)*Z(11)+AX(10,4)*Z(20)+AX(10,5)*Z(29)+AX(10,6)*Z(38)+AX(10,7)*
Z(47)+AX(10,8)*Z(56)+AX(10,9)*Z(65)+AX(10,10)*Z(74)+AX(10,11)*Z(83)+
AX(10,12)*Z(92)+AX(10,13)*Z(101)+AX(10,14)*Z(110)+AX(10,15)*Z(119)+A
X(10,16)*Z(128)+AX(10,17)*Z(137)+AX(10,18)*Z(146)+AX(10,19)*Z(155)+A
X(10,20)*S(50))
ZPRIME(75) = F1* (BY(4,1)*S(28)+SUM(BY(4,2:10)*Z(73:81))+BY(4,11)*S(29))+F2*(BX
(10,1)*S(4)+BX(10,2)*Z(3)+BX(10,3)*Z(12)+BX(10,4)*Z(21)+BX(10,5)*Z(30)+
BX(10,6)*Z(39)+BX(10,7)*Z(48)+BX(10,8)*Z(57)+BX(10,9)*Z(66)+BX(10,10)
*Z(75)+BX(10,11)*Z(84)+BX(10,12)*Z(93)+BX(10,13)*Z(102)+BX(10,14)*Z(1
11)+BX(10,15)*Z(120)+BX(10,16)*Z(129)+BX(10,17)*Z(138)+BX(10,18)*Z(14
7)+BX(10,19)*Z(156)+BX(10,20)*S(51))-F3*(AX(10,1)*S(4)+AX(10,2)* Z(3)+
AX(10,3)*Z(12)+AX(10,4)*Z(21)+AX(10,5)*Z(30)+AX(10,6)*Z(39)+AX(10,7)*
Z(48)+AX(10,8)*Z(57)+AX(10,9)*Z(66)+AX(10,10)*Z(75)+AX(10,11)*Z(84)+
AX(10,12)*Z(93)+AX(10,13)*Z(102)+AX(10,14)*Z(111)+AX(10,15)*Z(120)+A
X(10,16)*Z(129)+AX(10,17)*Z(138)+AX(10,18)*Z(147)+AX(10,19)*Z(156)+A
X(10,20)*S(51))
ZPRIME(76) = F1* (BY(5,1)*S(28)+SUM(BY(5,2:10)*Z(73:81))+BY(5,11)*S(29))+F2*(BX
(10,1)*S(5)+BX(10,2)*Z(4)+BX(10,3)*Z(13)+BX(10,4)*Z(22)+BX(10,5)*Z(31)+
BX(10,6)*Z(40)+BX(10,7)*Z(49)+BX(10,8)*Z(58)+BX(10,9)*Z(67)+BX(10,10)
*Z(76)+BX(10,11)*Z(85)+BX(10,12)*Z(94)+BX(10,13)*Z(103)+BX(10,14)*Z(1
12)+BX(10,15)*Z(121)+BX(10,16)*Z(130)+BX(10,17)*Z(139)+BX(10,18)*Z(14
8)+BX(10,19)*Z(157)+BX(10,20)*S(52))-F3*(AX(10,1)*S(5)+AX(10,2)* Z(4)+
AX(10,3)*Z(13)+AX(10,4)*Z(22)+AX(10,5)*Z(31)+AX(10,6)*Z(40)+AX(10,7)*
Z(49)+AX(10,8)*Z(58)+AX(10,9)*Z(67)+AX(10,10)*Z(76)+AX(10,11)*Z(85)+
AX(10,12)*Z(94)+AX(10,13)*Z(103)+AX(10,14)*Z(112)+AX(10,15)*Z(121)+A
X(10,16)*Z(130)+AX(10,17)*Z(139)+AX(10,18)*Z(148)+AX(10,19)*Z(157)+A
X(10,20)*S(52))
ZPRIME(77) = F1* (BY(6,1)*S(28)+SUM(BY(6,2:10)*Z(73:81))+BY(6,11)*S(29))+F2*(BX
(10,1)*S(6)+BX(10,2)*Z(5)+BX(10,3)*Z(14)+BX(10,4)*Z(23)+BX(10,5)*Z(32)+
BX(10,6)*Z(41)+BX(10,7)*Z(50)+BX(10,8)*Z(59)+BX(10,9)*Z(68)+BX(10,10)
*Z(77)+BX(10,11)*Z(86)+BX(10,12)*Z(95)+BX(10,13)*Z(104)+BX(10,14)*Z(1
13)+BX(10,15)*Z(122)+BX(10,16)*Z(131)+BX(10,17)*Z(140)+BX(10,18)*Z(14
9)+BX(10,19)*Z(158)+BX(10,20)*S(53))-F3*(AX(10,1)*S(6)+AX(10,2)* Z(5)+
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AX(10,3)*Z(14)+AX(10,4)*Z(23)+AX(10,5)*Z(32)+AX(10,6)*Z(41)+AX(10,7)*
Z(50)+AX(10,8)*Z(59)+AX(10,9)*Z(68)+AX(10,10)*Z(77)+AX(10,11)*Z(86)+
AX(10,12)*Z(95)+AX(10,13)*Z(104)+AX(10,14)*Z(113)+AX(10,15)*Z(122)+A
X(10,16)*Z(131)+AX(10,17)*Z(140)+AX(10,18)*Z(149)+AX(10,19)*Z(158)+A
X(10,20)*S(53))
ZPRIME(78) = F1* (BY(7,1)*S(28)+SUM(BY(7,2:10)*Z(73:81))+BY(7,11)*S(29))+F2*(BX
(10,1)*S(7)+BX(10,2)*Z(6)+BX(10,3)*Z(15)+BX(10,4)*Z(24)+BX(10,5)*Z(33)+
BX(10,6)*Z(42)+BX(10,7)*Z(51)+BX(10,8)*Z(60)+BX(10,9)*Z(69)+BX(10,10)
*Z(78)+BX(10,11)*Z(87)+BX(10,12)*Z(96)+BX(10,13)*Z(105)+BX(10,14)*Z(1
14)+BX(10,15)*Z(123)+BX(10,16)*Z(132)+BX(10,17)*Z(141)+BX(10,18)*Z(15
0)+BX(10,19)*Z(159)+BX(10,20)*S(54))-F3*(AX(10,1)*S(7)+AX(10,2)* Z(6)+
AX(10,3)*Z(15)+AX(10,4)*Z(24)+AX(10,5)*Z(33)+AX(10,6)*Z(42)+AX(10,7)*
Z(51)+AX(10,8)*Z(60)+AX(10,9)*Z(69)+AX(10,10)*Z(78)+AX(10,11)*Z(87)+
AX(10,12)*Z(96)+AX(10,13)*Z(105)+AX(10,14)*Z(114)+AX(10,15)*Z(123)+A
X(10,16)*Z(132)+AX(10,17)*Z(141)+AX(10,18)*Z(150)+AX(10,19)*Z(159)+A
X(10,20)*S(54))
ZPRIME(79) = F1* (BY(8,1)*S(28)+SUM(BY(8,2:10)*Z(73:81))+BY(8,11)*S(29))+F2*(BX
(10,1)*S(8)+BX(10,2)*Z(7)+BX(10,3)*Z(16)+BX(10,4)*Z(25)+BX(10,5)*Z(34)+
BX(10,6)*Z(43)+BX(10,7)*Z(52)+BX(10,8)*Z(61)+BX(10,9)*Z(70)+BX(10,10)
*Z(79)+BX(10,11)*Z(88)+BX(10,12)*Z(97)+BX(10,13)*Z(106)+BX(10,14)*Z(1
15)+BX(10,15)*Z(124)+BX(10,16)*Z(133)+BX(10,17)*Z(142)+BX(10,18)*Z(15
1)+BX(10,19)*Z(160)+BX(10,20)*S(55))-F3*(AX(10,1)*S(8)+AX(10,2)* Z(7)+
AX(10,3)*Z(16)+AX(10,4)*Z(25)+AX(10,5)*Z(34)+AX(10,6)*Z(43)+AX(10,7)*
Z(52)+AX(10,8)*Z(61)+AX(10,9)*Z(70)+AX(10,10)*Z(79)+AX(10,11)*Z(88)+
AX(10,12)*Z(97)+AX(10,13)*Z(106)+AX(10,14)*Z(115)+AX(10,15)*Z(124)+A
X(10,16)*Z(133)+AX(10,17)*Z(142)+AX(10,18)*Z(151)+AX(10,19)*Z(160)+A
X(10,20)*S(55))
ZPRIME(80) = F1* (BY(9,1)*S(28)+SUM(BY(9,2:10)*Z(73:81))+BY(9,11)*S(29))+F2*(BX
(10,1)*S(9)+BX(10,2)*Z(8)+BX(10,3)*Z(17)+BX(10,4)*Z(26)+BX(10,5)*Z(35)+
BX(10,6)*Z(44)+BX(10,7)*Z(53)+BX(10,8)*Z(62)+BX(10,9)*Z(71)+BX(10,10)
*Z(80)+BX(10,11)*Z(89)+BX(10,12)*Z(98)+BX(10,13)*Z(107)+BX(10,14)*Z(1
16)+BX(10,15)*Z(125)+BX(10,16)*Z(134)+BX(10,17)*Z(143)+BX(10,18)*Z(15
2)+BX(10,19)*Z(161)+BX(10,20)*S(56))-F3*(AX(10,1)*S(9)+AX(10,2)* Z(8)+
AX(10,3)*Z(17)+AX(10,4)*Z(26)+AX(10,5)*Z(35)+AX(10,6)*Z(44)+AX(10,7)*
Z(53)+AX(10,8)*Z(62)+AX(10,9)*Z(71)+AX(10,10)*Z(80)+AX(10,11)*Z(89)+
AX(10,12)*Z(98)+AX(10,13)*Z(107)+AX(10,14)*Z(116)+AX(10,15)*Z(125)+A
X(10,16)*Z(134)+AX(10,17)*Z(143)+AX(10,18)*Z(152)+AX(10,19)*Z(161)+A
X(10,20)*S(56))
ZPRIME(81) = F1*(BY(10,1)*S(28)+SUM(BY(10,2:10)*Z(73:81))+BY(10,11)*S(29))+F2*(BX
(10,1)*S(10)+BX(10,2)*Z(9)+BX(10,3)*Z(18)+BX(10,4)*Z(27)+BX(10,5)*Z(36)
+BX(10,6)*Z(45)+BX(10,7)*Z(54)+BX(10,8)*Z(63)+BX(10,9)*Z(72)+BX(10,10
)*Z(81)+BX(10,11)*Z(90)+BX(10,12)*Z(99)+BX(10,13)*Z(108)+BX(10,14)*Z(
117)+BX(10,15)*Z(126)+BX(10,16)*Z(135)+BX(10,17)*Z(144)+BX(10,18)*Z(1
53)+BX(10,19)*Z(162)+BX(10,20)*S(57))-F3*(AX(10,1)*S(10)+AX(10,2) *Z(9)
+AX(10,3)*Z(18)+AX(10,4)*Z(27)+AX(10,5)*Z(36)+AX(10,6)*Z(45)+AX(10,7)
*Z(54)+AX(10,8)*Z(63)+AX(10,9)*Z(72)+AX(10,10)*Z(81)+AX(10,11)*Z(90)+
AX(10,12)*Z(99)+AX(10,13)*Z(108)+AX(10,14)*Z(117)+AX(10,15)*Z(126)+A
X(10,16)*Z(135)+AX(10,17)*Z(144)+AX(10,18)*Z(153)+AX(10,19)*Z(162)+A
X(10,20)*S(57))
ZPRIME(82) = F1* (BY(2,1)*S(30)+SUM(BY(2,2:10)*Z(82:90))+BY(2,11)*S(31))+F2*(BX
(11,1)*S(2)+BX(11,2)*Z(1)+BX(11,3)*Z(10)+BX(11,4)*Z(19)+BX(11,5)*Z(28)+
BX(11,6)*Z(37)+BX(11,7)*Z(46)+BX(11,8)*Z(55)+BX(11,9)*Z(64)+BX(11,10)
*Z(73)+BX(11,11)*Z(82)+BX(11,12)*Z(91)+BX(11,13)*Z(100)+BX(11,14)*Z(1
09)+BX(11,15)*Z(118)+BX(11,16)*Z(127)+BX(11,17)*Z(136)+BX(11,18)*Z(14
5)+BX(11,19)*Z(154)+BX(11,20)*S(49))-F3*(AX(11,1)*S(2)+AX(11,2)* Z(1)+
AX(11,3)*Z(10)+AX(11,4)*Z(19)+AX(11,5)*Z(28)+AX(11,6)*Z(37)+AX(11,7)*
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Z(46)+AX(11,8)*Z(55)+AX(11,9)*Z(64)+AX(11,10)*Z(73)+AX(11,11)*Z(82)+AX(11,12)*Z(91)+AX(11,13)*Z(100)+AX(11,14)*Z(109)+AX(11,15)*Z(118)+AX(11,16)*Z(127)+AX(11,17)*Z(136)+AX(11,18)*Z(145)+AX(11,19)*Z(154)+AX(11,20)*S(49))

ZPRIME(83) = F1*(BY(3,1)*S(30)+SUM(BY(3,2:10)*Z(82:90))+BY(3,11)*S(31))+F2*(BX(11,1)*S(3)+BX(11,2)*Z(2)+BX(11,3)*Z(11)+BX(11,4)*Z(20)+BX(11,5)*Z(29)+BX(11,6)*Z(38)+BX(11,7)*Z(47)+BX(11,8)*Z(56)+BX(11,9)*Z(65)+BX(11,10)*Z(74)+BX(11,11)*Z(83)+BX(11,12)*Z(92)+BX(11,13)*Z(101)+BX(11,14)*Z(110)+BX(11,15)*Z(119)+BX(11,16)*Z(128)+BX(11,17)*Z(137)+BX(11,18)*Z(146)+BX(11,19)*Z(155)+BX(11,20)*S(50))-F3*(AX(11,1)*S(3)+AX(11,2)* Z(2)+AX(11,3)*Z(11)+AX(11,4)*Z(20)+AX(11,5)*Z(29)+AX(11,6)*Z(38)+AX(11,7)*Z(47)+AX(11,8)*Z(56)+AX(11,9)*Z(65)+AX(11,10)*Z(74)+AX(11,11)*Z(83)+AX(11,12)*Z(92)+AX(11,13)*Z(101)+AX(11,14)*Z(110)+AX(11,15)*Z(119)+AX(11,16)*Z(128)+AX(11,17)*Z(137)+AX(11,18)*Z(146)+AX(11,19)*Z(155)+AX(11,20)*S(50))

ZPRIME(84) = F1* (BY(4,1)*S(30)+SUM(BY(4,2:10)*Z(82:90))+BY(4,11)*S(31))+F2*(BX(11,1)*S(4)+BX(11,2)*Z(3)+BX(11,3)*Z(12)+BX(11,4)*Z(21)+BX(11,5)*Z(30)+BX(11,6)*Z(39)+BX(11,7)*Z(48)+BX(11,8)*Z(57)+BX(11,9)*Z(66)+BX(11,10)*Z(75)+BX(11,11)*Z(84)+BX(11,12)*Z(93)+BX(11,13)*Z(102)+BX(11,14)*Z(111)+BX(11,15)*Z(120)+BX(11,16)*Z(129)+BX(11,17)*Z(138)+BX(11,18)*Z(147)+BX(11,19)*Z(156)+BX(11,20)*S(51))-F3*(AX(11,1)*S(4)+AX(11,2)* Z(3)+AX(11,3)*Z(12)+AX(11,4)*Z(21)+AX(11,5)*Z(30)+AX(11,6)*Z(39)+AX(11,7)*Z(48)+AX(11,8)*Z(57)+AX(11,9)*Z(66)+AX(11,10)*Z(75)+AX(11,11)*Z(84)+AX(11,12)*Z(93)+AX(11,13)*Z(102)+AX(11,14)*Z(111)+AX(11,15)*Z(120)+AX(11,16)*Z(129)+AX(11,17)*Z(138)+AX(11,18)*Z(147)+AX(11,19)*Z(156)+AX(11,20)*S(51))

ZPRIME(85) = F1* (BY(5,1)*S(30)+SUM(BY(5,2:10)*Z(82:90))+BY(5,11)*S(31))+F2*(BX(11,1)*S(5)+BX(11,2)*Z(4)+BX(11,3)*Z(13)+BX(11,4)*Z(22)+BX(11,5)*Z(31)+BX(11,6)*Z(40)+BX(11,7)*Z(49)+BX(11,8)*Z(58)+BX(11,9)*Z(67)+BX(11,10)*Z(76)+BX(11,11)*Z(85)+BX(11,12)*Z(94)+BX(11,13)*Z(103)+BX(11,14)*Z(112)+BX(11,15)*Z(121)+BX(11,16)*Z(130)+BX(11,17)*Z(139)+BX(11,18)*Z(148)+BX(11,19)*Z(157)+BX(11,20)*S(52))-F3*(AX(11,1)*S(5)+AX(11,2)* Z(4)+AX(11,3)*Z(13)+AX(11,4)*Z(22)+AX(11,5)*Z(31)+AX(11,6)*Z(40)+AX(11,7)*Z(49)+AX(11,8)*Z(58)+AX(11,9)*Z(67)+AX(11,10)*Z(76)+AX(11,11)*Z(85)+AX(11,12)*Z(94)+AX(11,13)*Z(103)+AX(11,14)*Z(112)+AX(11,15)*Z(121)+AX(11,16)*Z(130)+AX(11,17)*Z(139)+AX(11,18)*Z(148)+AX(11,19)*Z(157)+AX(11,20)*S(52))

ZPRIME(86) = F1*(BY(6,1)*S(30)+SUM(BY(6,2:10)*Z(82:90))+BY(6,11)*S(31))+F2*(BX(11,1)*S(6)+BX(11,2)*Z(5)+BX(11,3)*Z(14)+BX(11,4)*Z(23)+BX(11,5)*Z(32)+BX(11,6)*Z(41)+BX(11,7)*Z(50)+BX(11,8)*Z(59)+BX(11,9)*Z(68)+BX(11,10)*Z(77)+BX(11,11)*Z(86)+BX(11,12)*Z(95)+BX(11,13)*Z(104)+BX(11,14)*Z(113)+BX(11,15)*Z(122)+BX(11,16)*Z(131)+BX(11,17)*Z(140)+BX(11,18)*Z(149)+BX(11,19)*Z(158)+BX(11,20)*S(53))-F3*(AX(11,1)*S(6)+AX(11,2)* Z(5)+AX(11,3)*Z(14)+AX(11,4)*Z(23)+AX(11,5)*Z(32)+AX(11,6)*Z(41)+AX(11,7)*Z(50)+AX(11,8)*Z(59)+AX(11,9)*Z(68)+AX(11,10)*Z(77)+AX(11,11)*Z(86)+AX(11,12)*Z(95)+AX(11,13)*Z(104)+AX(11,14)*Z(113)+AX(11,15)*Z(122)+AX(11,16)*Z(131)+AX(11,17)*Z(140)+AX(11,18)*Z(149)+AX(11,19)*Z(158)+AX(11,20)*S(53))

ZPRIME(87) = F1*(BY(7,1)*S(30)+SUM(BY(7,2:10)*Z(82:90))+BY(7,11)*S(31))+F2*(BX(11,1)*S(7)+BX(11,2)*Z(6)+BX(11,3)*Z(15)+BX(11,4)*Z(24)+BX(11,5)*Z(33)+BX(11,6)*Z(42)+BX(11,7)*Z(51)+BX(11,8)*Z(60)+BX(11,9)*Z(69)+BX(11,10)*Z(78)+BX(11,11)*Z(87)+BX(11,12)*Z(96)+BX(11,13)*Z(105)+BX(11,14)*Z(114)+BX(11,15)*Z(123)+BX(11,16)*Z(132)+BX(11,17)*Z(141)+BX(11,18)*Z(150)+BX(11,19)*Z(159)+BX(11,20)*S(54))-F3*(AX(11,1)*S(7)+AX(11,2)* Z(6)+AX(11,3)*Z(15)+AX(11,4)*Z(24)+AX(11,5)*Z(33)+AX(11,6)*Z(42)+AX(11,7)*Z(51)+AX(11,8)*Z(60)+AX(11,9)*Z(69)+AX(11,10)*Z(78)+AX(11,11)*Z(87)+

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                AX(11,12)*Z(96)+AX(11,13)*Z(105)+AX(11,14)*Z(114)+AX(11,15)*Z(123)+A
                X(11,16)*Z(132)+AX(11,17)*Z(141)+AX(11,18)*Z(150)+AX(11,19)*Z(159)+A
                X(11,20)*S(54))
ZPRIME(88) = F1*(BY(8,1)*S(30)+SUM(BY(8,2:10)*Z(82:90))+BY(8,11)*S(31))+F2*(BX
                (11,1)*S(8)+BX(11,2)*Z(7)+BX(11,3)*Z(16)+BX(11,4)*Z(25)+BX(11,5)*Z(34)+
                BX(11,6)*Z(43)+BX(11,7)*Z(52)+BX(11,8)*Z(61)+BX(11,9)*Z(70)+BX(11,10)
                *Z(79)+BX(11,11)*Z(88)+BX(11,12)*Z(97)+BX(11,13)*Z(106)+BX(11,14)*Z(1
                15)+BX(11,15)*Z(124)+BX(11,16)*Z(133)+BX(11,17)*Z(142)+BX(11,18)*Z(15
                1)+BX(11,19)*Z(160)+BX(11,20)*S(55))-F3*(AX(11,1)*S(8)+AX(11,2)* Z(7)+
                AX(11,3)*Z(16)+AX(11,4)*Z(25)+AX(11,5)*Z(34)+AX(11,6)*Z(43)+AX(11,7)*
                Z(52)+AX(11,8)*Z(61)+AX(11,9)*Z(70)+AX(11,10)*Z(79)+AX(11,11)*Z(88)+
                AX(11,12)*Z(97)+AX(11,13)*Z(106)+AX(11,14)*Z(115)+AX(11,15)*Z(124)+A
                X(11,16)*Z(133)+AX(11,17)*Z(142)+AX(11,18)*Z(151)+AX(11,19)*Z(160)+A
                X(11,20)*S(55))
ZPRIME(89) = F1*(BY(9,1)*S(30)+SUM(BY(9,2:10)*Z(82:90))+BY(9,11)*S(31))+F2*(BX
                (11,1)*S(9)+BX(11,2)*Z(8)+BX(11,3)*Z(17)+BX(11,4)*Z(26)+BX(11,5)*Z(35)+
                BX(11,6)*Z(44)+BX(11,7)*Z(53)+BX(11,8)*Z(62)+BX(11,9)*Z(71)+BX(11,10)
                *Z(80)+BX(11,11)*Z(89)+BX(11,12)*Z(98)+BX(11,13)*Z(107)+BX(11,14)*Z(1
                16)+BX(11,15)*Z(125)+BX(11,16)*Z(134)+BX(11,17)*Z(143)+BX(11,18)*Z(15
                2)+BX(11,19)*Z(161)+BX(11,20)*S(56))-F3*(AX(11,1)*S(9)+AX(11,2)* Z(8)+
                AX(11,3)*Z(17)+AX(11,4)*Z(26)+AX(11,5)*Z(35)+AX(11,6)*Z(44)+AX(11,7)*
                Z(53)+AX(11,8)*Z(62)+AX(11,9)*Z(71)+AX(11,10)*Z(80)+AX(11,11)*Z(89)+
                AX(11,12)*Z(98)+AX(11,13)*Z(107)+AX(11,14)*Z(116)+AX(11,15)*Z(125)+A
                X(11,16)*Z(134)+AX(11,17)*Z(143)+AX(11,18)*Z(152)+AX(11,19)*Z(161)+A
                X(11,20)*S(56))
ZPRIME(90) = F1*(BY(10,1)*S(30)+SUM(BY(10,2:10)*Z(82:90))+BY(10,11)*S(31))+F2*(BX
                (11,1)*S(10)+BX(11,2)*Z(9)+BX(11,3)*Z(18)+BX(11,4)*Z(27)+BX(11,5)*Z(36)
                +BX(11,6)*Z(45)+BX(11,7)*Z(54)+BX(11,8)*Z(63)+BX(11,9)*Z(72)+BX(11,10
                )*Z(81)+BX(11,11)*Z(90)+BX(11,12)*Z(99)+BX(11,13)*Z(108)+BX(11,14)*Z(
                117)+BX(11,15)*Z(126)+BX(11,16)*Z(135)+BX(11,17)*Z(144)+BX(11,18)*Z(1
                53)+BX(11,19)*Z(162)+BX(11,20)*S(57))-F3*(AX(11,1)*S(10)+AX(11,2) *Z(9)
                +AX(11,3)*Z(18)+AX(11,4)*Z(27)+AX(11,5)*Z(36)+AX(11,6)*Z(45)+AX(11,7)
                *Z(54)+AX(11,8)*Z(63)+AX(11,9)*Z(72)+AX(11,10)*Z(81)+AX(11,11)*Z(90)+
                AX(11,12)*Z(99)+AX(11,13)*Z(108)+AX(11,14)*Z(117)+AX(11,15)*Z(126)+A
                X(11,16)*Z(135)+AX(11,17)*Z(144)+AX(11,18)*Z(153)+AX(11,19)*Z(162)+A
                X(11,20)*S(57))
ZPRIME(91) = F1*(BY(2,1)*S(32)+SUM(BY(2,2:10)*Z(91:99))+BY(2,11)*S(33))+F2*(BX
                (12,1)*S(2)+BX(12,2)*Z(1)+BX(12,3)*Z(10)+BX(12,4)*Z(19)+BX(12,5)*Z(28)+
                BX(12,6)*Z(37)+BX(12,7)*Z(46)+BX(12,8)*Z(55)+BX(12,9)*Z(64)+BX(12,10)
                *Z(73)+BX(12,11)*Z(82)+BX(12,12)*Z(91)+BX(12,13)*Z(100)+BX(12,14)*Z(1
                09)+BX(12,15)*Z(118)+BX(12,16)*Z(127)+BX(12,17)*Z(136)+BX(12,18)*Z(14
                5)+BX(12,19)*Z(154)+BX(12,20)*S(49))-F3*(AX(12,1)*S(2)+AX(12,2)* Z(1)+
                AX(12,3)*Z(10)+AX(12,4)*Z(19)+AX(12,5)*Z(28)+AX(12,6)*Z(37)+AX(12,7)*
                Z(46)+AX(12,8)*Z(55)+AX(12,9)*Z(64)+AX(12,10)*Z(73)+AX(12,11)*Z(82)+
                AX(12,12)*Z(91)+AX(12,13)*Z(100)+AX(12,14)*Z(109)+AX(12,15)*Z(118)+A
                X(12,16)*Z(127)+AX(12,17)*Z(136)+AX(12,18)*Z(145)+AX(12,19)*Z(154)+A
                X(12,20)*S(49))
ZPRIME(92) =  F1*(BY(3,1)*S(32)+SUM(BY(3,2:10)*Z(91:99))+BY(3,11)*S(33))+F2*(BX
                (12,1)*S(3)+BX(12,2)*Z(2)+BX(12,3)*Z(11)+BX(12,4)*Z(20)+BX(12,5)*Z(29)+
                BX(12,6)*Z(38)+BX(12,7)*Z(47)+BX(12,8)*Z(56)+BX(12,9)*Z(65)+BX(12,10)
                *Z(74)+BX(12,11)*Z(83)+BX(12,12)*Z(92)+BX(12,13)*Z(101)+BX(12,14)*Z(1
                10)+BX(12,15)*Z(119)+BX(12,16)*Z(128)+BX(12,17)*Z(137)+BX(12,18)*Z(14
                6)+BX(12,19)*Z(155)+BX(12,20)*S(50))-F3*(AX(12,1)*S(3)+AX(12,2)* Z(2)+
                AX(12,3)*Z(11)+AX(12,4)*Z(20)+AX(12,5)*Z(29)+AX(12,6)*Z(38)+AX(12,7)*
                Z(47)+AX(12,8)*Z(56)+AX(12,9)*Z(65)+AX(12,10)*Z(74)+AX(12,11)*Z(83)+
                AX(12,12)*Z(92)+AX(12,13)*Z(101)+AX(12,14)*Z(110)+AX(12,15)*Z(119)+A
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X(12,16)*Z(128)+AX(12,17)*Z(137)+AX(12,18)*Z(146)+AX(12,19)*Z(155)+A
X(12,20)*S(50))
ZPRIME(93) = F1*(BY(4,1)*S(32)+SUM(BY(4,2:10)*Z(91:99))+BY(4,11)*S(33))+F2*(BX
(12,1)*S(4)+BX(12,2)*Z(3)+BX(12,3)*Z(12)+BX(12,4)*Z(21)+BX(12,5)*Z(30)+
BX(12,6)*Z(39)+BX(12,7)*Z(48)+BX(12,8)*Z(57)+BX(12,9)*Z(66)+BX(12,10)
*Z(75)+BX(12,11)*Z(84)+BX(12,12)*Z(93)+BX(12,13)*Z(102)+BX(12,14)*Z(1
11)+BX(12,15)*Z(120)+BX(12,16)*Z(129)+BX(12,17)*Z(138)+BX(12,18)*Z(14
7)+BX(12,19)*Z(156)+BX(12,20)*S(51))-F3*(AX(12,1)*S(4)+AX(12,2)* Z(3)+
AX(12,3)*Z(12)+AX(12,4)*Z(21)+AX(12,5)*Z(30)+AX(12,6)*Z(39)+AX(12,7)*
Z(48)+AX(12,8)*Z(57)+AX(12,9)*Z(66)+AX(12,10)*Z(75)+AX(12,11)*Z(84)+
AX(12,12)*Z(93)+AX(12,13)*Z(102)+AX(12,14)*Z(111)+AX(12,15)*Z(120)+A
X(12,16)*Z(129)+AX(12,17)*Z(138)+AX(12,18)*Z(147)+AX(12,19)*Z(156)+A
X(12,20)*S(51))
ZPRIME(94) = F1*(BY(5,1)*S(32)+SUM(BY(5,2:10)*Z(91:99))+BY(5,11)*S(33))+F2*(BX
(12,1)*S(5)+BX(12,2)*Z(4)+BX(12,3)*Z(13)+BX(12,4)*Z(22)+BX(12,5)*Z(31)+
BX(12,6)*Z(40)+BX(12,7)*Z(49)+BX(12,8)*Z(58)+BX(12,9)*Z(67)+BX(12,10)
*Z(76)+BX(12,11)*Z(85)+BX(12,12)*Z(94)+BX(12,13)*Z(103)+BX(12,14)*Z(1
12)+BX(12,15)*Z(121)+BX(12,16)*Z(130)+BX(12,17)*Z(139)+BX(12,18)*Z(14
8)+BX(12,19)*Z(157)+BX(12,20)*S(52))-F3*(AX(12,1)*S(5)+AX(12,2)* Z(4)+
AX(12,3)*Z(13)+AX(12,4)*Z(22)+AX(12,5)*Z(31)+AX(12,6)*Z(40)+AX(12,7)*
Z(49)+AX(12,8)*Z(58)+AX(12,9)*Z(67)+AX(12,10)*Z(76)+AX(12,11)*Z(85)+
AX(12,12)*Z(94)+AX(12,13)*Z(103)+AX(12,14)*Z(112)+AX(12,15)*Z(121)+A
X(12,16)*Z(130)+AX(12,17)*Z(139)+AX(12,18)*Z(148)+AX(12,19)*Z(157)+A
X(12,20)*S(52))
ZPRIME(95) = F1*(BY(6,1)*S(32)+SUM(BY(6,2:10)*Z(91:99))+BY(6,11)*S(33))+F2*(BX
(12,1)*S(6)+BX(12,2)*Z(5)+BX(12,3)*Z(14)+BX(12,4)*Z(23)+BX(12,5)*Z(32)+
BX(12,6)*Z(41)+BX(12,7)*Z(50)+BX(12,8)*Z(59)+BX(12,9)*Z(68)+BX(12,10)
*Z(77)+BX(12,11)*Z(86)+BX(12,12)*Z(95)+BX(12,13)*Z(104)+BX(12,14)*Z(1
13)+BX(12,15)*Z(122)+BX(12,16)*Z(131)+BX(12,17)*Z(140)+BX(12,18)*Z(14
9)+BX(12,19)*Z(158)+BX(12,20)*S(53))-F3*(AX(12,1)*S(6)+AX(12,2)* Z(5)+
AX(12,3)*Z(14)+AX(12,4)*Z(23)+AX(12,5)*Z(32)+AX(12,6)*Z(41)+AX(12,7)*
Z(50)+AX(12,8)*Z(59)+AX(12,9)*Z(68)+AX(12,10)*Z(77)+AX(12,11)*Z(86)+
AX(12,12)*Z(95)+AX(12,13)*Z(104)+AX(12,14)*Z(113)+AX(12,15)*Z(122)+A
X(12,16)*Z(131)+AX(12,17)*Z(140)+AX(12,18)*Z(149)+AX(12,19)*Z(158)+A
X(12,20)*S(53))
ZPRIME(96) = F1*(BY(7,1)*S(32)+SUM(BY(7,2:10)*Z(91:99))+BY(7,11)*S(33))+F2*(BX
(12,1)*S(7)+BX(12,2)*Z(6)+BX(12,3)*Z(15)+BX(12,4)*Z(24)+BX(12,5)*Z(33)+
BX(12,6)*Z(42)+BX(12,7)*Z(51)+BX(12,8)*Z(60)+BX(12,9)*Z(69)+BX(12,10)
*Z(78)+BX(12,11)*Z(87)+BX(12,12)*Z(96)+BX(12,13)*Z(105)+BX(12,14)*Z(1
14)+BX(12,15)*Z(123)+BX(12,16)*Z(132)+BX(12,17)*Z(141)+BX(12,18)*Z(15
0)+BX(12,19)*Z(159)+BX(12,20)*S(54))-F3*(AX(12,1)*S(7)+AX(12,2)* Z(6)+
AX(12,3)*Z(15)+AX(12,4)*Z(24)+AX(12,5)*Z(33)+AX(12,6)*Z(42)+AX(12,7)*
Z(51)+AX(12,8)*Z(60)+AX(12,9)*Z(69)+AX(12,10)*Z(78)+AX(12,11)*Z(87)+
AX(12,12)*Z(96)+AX(12,13)*Z(105)+AX(12,14)*Z(114)+AX(12,15)*Z(123)+A
X(12,16)*Z(132)+AX(12,17)*Z(141)+AX(12,18)*Z(150)+AX(12,19)*Z(159)+A
X(12,20)*S(54))
ZPRIME(97) = F1*(BY(8,1)*S(32)+SUM(BY(8,2:10)*Z(91:99))+BY(8,11)*S(33))+F2*(BX
(12,1)*S(8)+BX(12,2)*Z(7)+BX(12,3)*Z(16)+BX(12,4)*Z(25)+BX(12,5)*Z(34)+
BX(12,6)*Z(43)+BX(12,7)*Z(52)+BX(12,8)*Z(61)+BX(12,9)*Z(70)+BX(12,10)
*Z(79)+BX(12,11)*Z(88)+BX(12,12)*Z(97)+BX(12,13)*Z(106)+BX(12,14)*Z(1
15)+BX(12,15)*Z(124)+BX(12,16)*Z(133)+BX(12,17)*Z(142)+BX(12,18)*Z(15
1)+BX(12,19)*Z(160)+BX(12,20)*S(55))-F3*(AX(12,1)*S(8)+AX(12,2)* Z(7)+
AX(12,3)*Z(16)+AX(12,4)*Z(25)+AX(12,5)*Z(34)+AX(12,6)*Z(43)+AX(12,7)*
Z(52)+AX(12,8)*Z(61)+AX(12,9)*Z(70)+AX(12,10)*Z(79)+AX(12,11)*Z(88)+
AX(12,12)*Z(97)+AX(12,13)*Z(106)+AX(12,14)*Z(115)+AX(12,15)*Z(124)+A
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X(12,16)*Z(133)+AX(12,17)*Z(142)+AX(12,18)*Z(151)+AX(12,19)*Z(160)+A
X(12,20)*S(55))

ZPRIME(98) = F1*(BY(9,1)*S(32)+SUM(BY(9,2:10)*Z(91:99))+BY(9,11)*S(33))+F2*(BX
(12,1)*S(9)+BX(12,2)*Z(8)+BX(12,3)*Z(17)+BX(12,4)*Z(26)+BX(12,5)*Z(35)+
BX(12,6)*Z(44)+BX(12,7)*Z(53)+BX(12,8)*Z(62)+BX(12,9)*Z(71)+BX(12,10)
*Z(80)+BX(12,11)*Z(89)+BX(12,12)*Z(98)+BX(12,13)*Z(107)+BX(12,14)*Z(1
16)+BX(12,15)*Z(125)+BX(12,16)*Z(134)+BX(12,17)*Z(143)+BX(12,18)*Z(15
2)+BX(12,19)*Z(161)+BX(12,20)*S(56))-F3*(AX(12,1)*S(9)+AX(12,2)* Z(8)+
AX(12,3)*Z(17)+AX(12,4)*Z(26)+AX(12,5)*Z(35)+AX(12,6)*Z(44)+AX(12,7)*
Z(53)+AX(12,8)*Z(62)+AX(12,9)*Z(71)+AX(12,10)*Z(80)+AX(12,11)*Z(89)+
AX(12,12)*Z(98)+AX(12,13)*Z(107)+AX(12,14)*Z(116)+AX(12,15)*Z(125)+A
X(12,16)*Z(134)+AX(12,17)*Z(143)+AX(12,18)*Z(152)+AX(12,19)*Z(161)+A
X(12,20)*S(56))

ZPRIME(99) = F1*(BY(10,1)*S(32)+SUM(BY(10,2:10)*Z(91:99))+BY(10,11)*S(33))+F2*(BX
(12,1)*S(10)+BX(12,2)*Z(9)+BX(12,3)*Z(18)+BX(12,4)*Z(27)+BX(12,5)*Z(36)
+BX(12,6)*Z(45)+BX(12,7)*Z(54)+BX(12,8)*Z(63)+BX(12,9)*Z(72)+BX(12,10
)*Z(81)+BX(12,11)*Z(90)+BX(12,12)*Z(99)+BX(12,13)*Z(108)+BX(12,14)*Z(
117)+BX(12,15)*Z(126)+BX(12,16)*Z(135)+BX(12,17)*Z(144)+BX(12,18)*Z(1
53)+BX(12,19)*Z(162)+BX(12,20)*S(57))-F3*(AX(12,1)*S(10)+AX(12,2)
*Z(9)+AX(12,3)*Z(18)+AX(12,4)*Z(27)+AX(12,5)*Z(36)+AX(12,6)*Z(45)+AX
(12,7)*Z(54)+AX(12,8)*Z(63)+AX(12,9)*Z(72)+AX(12,10)*Z(81)+AX(12,11)*
Z(90)+AX(12,12)*Z(99)+AX(12,13)*Z(108)+AX(12,14)*Z(117)+AX(12,15)*Z(1
26)+AX(12,16)*Z(135)+AX(12,17)*Z(144)+AX(12,18)*Z(153)+AX(12,19)*Z(16
2)+AX(12,20)*S(57))

ZPRIME(100) = F1*(BY(2,1)*S(34)+SUM(BY(2,2:10)*Z(100:108))+BY(2,11)*S(35))+F2*(BX
(13,1)*S(2)+BX(13,2)*Z(1)+BX(13,3)*Z(10)+BX(13,4)*Z(19)+BX(13,5)*Z(28)+
BX(13,6)*Z(37)+BX(13,7)*Z(46)+BX(13,8)*Z(55)+BX(13,9)*Z(64)+BX(13,10)
*Z(73)+BX(13,11)*Z(82)+BX(13,12)*Z(91)+BX(13,13)*Z(100)+BX(13,14)*Z(1
09)+BX(13,15)*Z(118)+BX(13,16)*Z(127)+BX(13,17)*Z(136)+BX(13,18)*Z(14
5)+BX(13,19)*Z(154)+BX(13,20)*S(49))-F3*(AX(13,1)*S(2)+AX(13,2) *Z(1)+
AX(13,3)*Z(10)+AX(13,4)*Z(19)+AX(13,5)*Z(28)+AX(13,6)*Z(37)+AX(13,7)*
Z(46)+AX(13,8)*Z(55)+AX(13,9)*Z(64)+AX(13,10)*Z(73)+AX(13,11)*Z(82)+
AX(13,12)*Z(91)+AX(13,13)*Z(100)+AX(13,14)*Z(109)+AX(13,15)*Z(118)+A
X(13,16)*Z(127)+AX(13,17)*Z(136)+AX(13,18)*Z(145)+AX(13,19)*Z(154)+A
X(13,20)*S(49))

ZPRIME(101) = F1*(BY(3,1)*S(34)+SUM(BY(3,2:10)*Z(100:108))+BY(3,11)*S(35))+F2*(BX
(13,1)*S(3)+BX(13,2)*Z(2)+BX(13,3)*Z(11)+BX(13,4)*Z(20)+BX(13,5)*Z(29)+
BX(13,6)*Z(38)+BX(13,7)*Z(47)+BX(13,8)*Z(56)+BX(13,9)*Z(65)+BX(13,10)
*Z(74)+BX(13,11)*Z(83)+BX(13,12)*Z(92)+BX(13,13)*Z(101)+BX(13,14)*Z(1
10)+BX(13,15)*Z(119)+BX(13,16)*Z(128)+BX(13,17)*Z(137)+BX(13,18)*Z(14
6)+BX(13,19)*Z(155)+BX(13,20)*S(50))-F3*(AX(13,1)*S(3)+AX(13,2) *Z(2)+
AX(13,3)*Z(11)+AX(13,4)*Z(20)+AX(13,5)*Z(29)+AX(13,6)*Z(38)+AX(13,7)*
Z(47)+AX(13,8)*Z(56)+AX(13,9)*Z(65)+AX(13,10)*Z(74)+AX(13,11)*Z(83)+
AX(13,12)*Z(92)+AX(13,13)*Z(101)+AX(13,14)*Z(110)+AX(13,15)*Z(119)+A
X(13,16)*Z(128)+AX(13,17)*Z(137)+AX(13,18)*Z(146)+AX(13,19)*Z(155)+A
X(13,20)*S(50))

ZPRIME(102) = F1*(BY(4,1)*S(34)+SUM(BY(4,2:10)*Z(100:108))+BY(4,11)*S(35))+F2*(BX
(13,1)*S(4)+BX(13,2)*Z(3)+BX(13,3)*Z(12)+BX(13,4)*Z(21)+BX(13,5)*Z(30)+
BX(13,6)*Z(39)+BX(13,7)*Z(48)+BX(13,8)*Z(57)+BX(13,9)*Z(66)+BX(13,10)
*Z(75)+BX(13,11)*Z(84)+BX(13,12)*Z(93)+BX(13,13)*Z(102)+BX(13,14)*Z(1
11)+BX(13,15)*Z(120)+BX(13,16)*Z(129)+BX(13,17)*Z(138)+BX(13,18)*Z(14
7)+BX(13,19)*Z(156)+BX(13,20)*S(51))-F3*(AX(13,1)*S(4)+AX(13,2) *Z(3)+
AX(13,3)*Z(12)+AX(13,4)*Z(21)+AX(13,5)*Z(30)+AX(13,6)*Z(39)+AX(13,7)*
Z(48)+AX(13,8)*Z(57)+AX(13,9)*Z(66)+AX(13,10)*Z(75)+AX(13,11)*Z(84)+
AX(13,12)*Z(93)+AX(13,13)*Z(102)+AX(13,14)*Z(111)+AX(13,15)*Z(120)+A

X(13,16)*Z(129)+AX(13,17)*Z(138)+AX(13,18)*Z(147)+AX(13,19)*Z(156)+A
X(13,20)*S(51))

ZPRIME(103) = F1*(BY(5,1)*S(34)+SUM(BY(5,2:10)*Z(100:108))+BY(5,11)*S(35))+F2*(BX
(13,1)*S(5)+BX(13,2)*Z(4)+BX(13,3)*Z(13)+BX(13,4)*Z(22)+BX(13,5)*Z(31)+
BX(13,6)*Z(40)+BX(13,7)*Z(49)+BX(13,8)*Z(58)+BX(13,9)*Z(67)+BX(13,10)
*Z(76)+BX(13,11)*Z(85)+BX(13,12)*Z(94)+BX(13,13)*Z(103)+BX(13,14)*Z(1
12)+BX(13,15)*Z(121)+BX(13,16)*Z(130)+BX(13,17)*Z(139)+BX(13,18)*Z(14
8)+BX(13,19)*Z(157)+BX(13,20)*S(52))-F3*(AX(13,1)*S(5)+AX(13,2) *Z(4)+
AX(13,3)*Z(13)+AX(13,4)*Z(22)+AX(13,5)*Z(31)+AX(13,6)*Z(40)+AX(13,7)*
Z(49)+AX(13,8)*Z(58)+AX(13,9)*Z(67)+AX(13,10)*Z(76)+AX(13,11)*Z(85)+
AX(13,12)*Z(94)+AX(13,13)*Z(103)+AX(13,14)*Z(112)+AX(13,15)*Z(121)+A
X(13,16)*Z(130)+AX(13,17)*Z(139)+AX(13,18)*Z(148)+AX(13,19)*Z(157)+A
X(13,20)*S(52))

ZPRIME(104) = F1*(BY(6,1)*S(34)+SUM(BY(6,2:10)*Z(100:108))+BY(6,11)*S(35))+F2*(BX
(13,1)*S(6)+BX(13,2)*Z(5)+BX(13,3)*Z(14)+BX(13,4)*Z(23)+BX(13,5)*Z(32)+
BX(13,6)*Z(41)+BX(13,7)*Z(50)+BX(13,8)*Z(59)+BX(13,9)*Z(68)+BX(13,10)
*Z(77)+BX(13,11)*Z(86)+BX(13,12)*Z(95)+BX(13,13)*Z(104)+BX(13,14)*Z(1
13)+BX(13,15)*Z(122)+BX(13,16)*Z(131)+BX(13,17)*Z(140)+BX(13,18)*Z(14
9)+BX(13,19)*Z(158)+BX(13,20)*S(53))-F3*(AX(13,1)*S(6)+AX(13,2) *Z(5)+
AX(13,3)*Z(14)+AX(13,4)*Z(23)+AX(13,5)*Z(32)+AX(13,6)*Z(41)+AX(13,7)*
Z(50)+AX(13,8)*Z(59)+AX(13,9)*Z(68)+AX(13,10)*Z(77)+AX(13,11)*Z(86)+
AX(13,12)*Z(95)+AX(13,13)*Z(104)+AX(13,14)*Z(113)+AX(13,15)*Z(122)+A
X(13,16)*Z(131)+AX(13,17)*Z(140)+AX(13,18)*Z(149)+AX(13,19)*Z(158)+A
X(13,20)*S(53))

ZPRIME(105) = F1*(BY(7,1)*S(34)+SUM(BY(7,2:10)*Z(100:108))+BY(7,11)*S(35))+F2*(BX
(13,1)*S(7)+BX(13,2)*Z(6)+BX(13,3)*Z(15)+BX(13,4)*Z(24)+BX(13,5)*Z(33)+
BX(13,6)*Z(42)+BX(13,7)*Z(51)+BX(13,8)*Z(60)+BX(13,9)*Z(69)+BX(13,10)
*Z(78)+BX(13,11)*Z(87)+BX(13,12)*Z(96)+BX(13,13)*Z(105)+BX(13,14)*Z(1
14)+BX(13,15)*Z(123)+BX(13,16)*Z(132)+BX(13,17)*Z(141)+BX(13,18)*Z(15
0)+BX(13,19)*Z(159)+BX(13,20)*S(54))-F3*(AX(13,1)*S(7)+AX(13,2) *Z(6)+
AX(13,3)*Z(15)+AX(13,4)*Z(24)+AX(13,5)*Z(33)+AX(13,6)*Z(42)+AX(13,7)*
Z(51)+AX(13,8)*Z(60)+AX(13,9)*Z(69)+AX(13,10)*Z(78)+AX(13,11)*Z(87)+
AX(13,12)*Z(96)+AX(13,13)*Z(105)+AX(13,14)*Z(114)+AX(13,15)*Z(123)+A
X(13,16)*Z(132)+AX(13,17)*Z(141)+AX(13,18)*Z(150)+AX(13,19)*Z(159)+A
X(13,20)*S(54))

ZPRIME(106) = F1*(BY(8,1)*S(34)+SUM(BY(8,2:10)*Z(100:108))+BY(8,11)*S(35))+F2*(BX
(13,1)*S(8)+BX(13,2)*Z(7)+BX(13,3)*Z(16)+BX(13,4)*Z(25)+BX(13,5)*Z(34)+
BX(13,6)*Z(43)+BX(13,7)*Z(52)+BX(13,8)*Z(61)+BX(13,9)*Z(70)+BX(13,10)
*Z(79)+BX(13,11)*Z(88)+BX(13,12)*Z(97)+BX(13,13)*Z(106)+BX(13,14)*Z(1
15)+BX(13,15)*Z(124)+BX(13,16)*Z(133)+BX(13,17)*Z(142)+BX(13,18)*Z(15
1)+BX(13,19)*Z(160)+BX(13,20)*S(55))-F3*(AX(13,1)*S(8)+AX(13,2) *Z(7)+
AX(13,3)*Z(16)+AX(13,4)*Z(25)+AX(13,5)*Z(34)+AX(13,6)*Z(43)+AX(13,7)*
Z(52)+AX(13,8)*Z(61)+AX(13,9)*Z(70)+AX(13,10)*Z(79)+AX(13,11)*Z(88)+
AX(13,12)*Z(97)+AX(13,13)*Z(106)+AX(13,14)*Z(115)+AX(13,15)*Z(124)+A
X(13,16)*Z(133)+AX(13,17)*Z(142)+AX(13,18)*Z(151)+AX(13,19)*Z(160)+A
X(13,20)*S(55))

ZPRIME(107) = F1*(BY(9,1)*S(34)+SUM(BY(9,2:10)*Z(100:108))+BY(9,11)*S(35))+F2*(BX
(13,1)*S(9)+BX(13,2)*Z(8)+BX(13,3)*Z(17)+BX(13,4)*Z(26)+BX(13,5)*Z(35)+
BX(13,6)*Z(44)+BX(13,7)*Z(53)+BX(13,8)*Z(62)+BX(13,9)*Z(71)+BX(13,10)
*Z(80)+BX(13,11)*Z(89)+BX(13,12)*Z(98)+BX(13,13)*Z(107)+BX(13,14)*Z(1
16)+BX(13,15)*Z(125)+BX(13,16)*Z(134)+BX(13,17)*Z(143)+BX(13,18)*Z(15
2)+BX(13,19)*Z(161)+BX(13,20)*S(56))-F3*(AX(13,1)*S(9)+AX(13,2) *Z(8)+
AX(13,3)*Z(17)+AX(13,4)*Z(26)+AX(13,5)*Z(35)+AX(13,6)*Z(44)+AX(13,7)*
Z(53)+AX(13,8)*Z(62)+AX(13,9)*Z(71)+AX(13,10)*Z(80)+AX(13,11)*Z(89)+
AX(13,12)*Z(98)+AX(13,13)*Z(107)+AX(13,14)*Z(116)+AX(13,15)*Z(125)+A

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                 X(13,16)*Z(134)+AX(13,17)*Z(143)+AX(13,18)*Z(152)+AX(13,19)*Z(161)+A
                 X(13,20)*S(56))
ZPRIME(108) = F1*(BY(10,1)*S(34)+SUM(BY(10,2:10)*Z(100:108))+BY(10,11)*S(35))+F2*
                 (BX(13,1)*S(10)+BX(13,2)*Z(9)+BX(13,3)*Z(18)+BX(13,4)*Z(27)+BX(13,5)*Z
                 (36)+BX(13,6)*Z(45)+BX(13,7)*Z(54)+BX(13,8)*Z(63)+BX(13,9)*Z(72)+BX(1
                 3,10)*Z(81)+BX(13,11)*Z(90)+BX(13,12)*Z(99)+BX(13,13)*Z(108)+BX(13,14)
                 *Z(117)+BX(13,15)*Z(126)+BX(13,16)*Z(135)+BX(13,17)*Z(144)+BX(13,18)*
                 Z(153)+BX(13,19)*Z(162)+BX(13,20)*S(57))-F3*(AX(13,1)*S(10)+AX (13,2) *
                 Z(9)+AX(13,3)*Z(18)+AX(13,4)*Z(27)+AX(13,5)*Z(36)+AX(13,6)*Z(45)+AX(
                 13,7)*Z(54)+AX(13,8)*Z(63)+AX(13,9)*Z(72)+AX(13,10)*Z(81)+AX(13,11)*Z
                 (90)+AX(13,12)*Z(99)+AX(13,13)*Z(108)+AX(13,14)*Z(117)+AX(13,15)*Z(12
                 6)+AX(13,16)*Z(135)+AX(13,17)*Z(144)+AX(13,18)*Z(153)+AX(13,19)*Z(162
                 )+AX(13,20)*S(57))
ZPRIME(109) = F1*(BY(2,1)*S(36)+SUM(BY(2,2:10)*Z(109:117))+BY(2,11)*S(37))+F2*
                 (BX(14,1)*S(2)+BX(14,2)*Z(1)+BX(14,3)*Z(10)+BX(14,4)*Z(19)+BX(14,5)*Z(
                 28)+BX(14,6)*Z(37)+BX(14,7)*Z(46)+BX(14,8)*Z(55)+BX(14,9)*Z(64)+BX(14
                 ,10)*Z(73)+BX(14,11)*Z(82)+BX(14,12)*Z(91)+BX(14,13)*Z(100)+BX(14,14)*
                 Z(109)+BX(14,15)*Z(118)+BX(14,16)*Z(127)+BX(14,17)*Z(136)+BX(14,18)*Z
                 (145)+BX(14,19)*Z(154)+BX(14,20)*S(49))-F3*(AX(14,1)*S(2)+AX (14,2)*
                 Z(1)+AX(14,3)*Z(10)+AX(14,4)*Z(19)+AX(14,5)*Z(28)+AX(14,6)*Z(37)+AX(
                 14,7)*Z(46)+AX(14,8)*Z(55)+AX(14,9)*Z(64)+AX(14,10)*Z(73)+AX(14,11)*Z
                 (82)+AX(14,12)*Z(91)+AX(14,13)*Z(100)+AX(14,14)*Z(109)+AX(14,15)*Z(11
                 8)+AX(14,16)*Z(127)+AX(14,17)*Z(136)+AX(14,18)*Z(145)+AX(14,19)*Z(154
                 )+AX(14,20)*S(49))
ZPRIME(110) = F1*(BY(3,1)*S(36)+SUM(BY(3,2:10)*Z(109:117))+BY(3,11)*S(37))+F2*
                 (BX(14,1)*S(3)+BX(14,2)*Z(2)+BX(14,3)*Z(11)+BX(14,4)*Z(20)+BX(14,5)*Z(
                 29)+BX(14,6)*Z(38)+BX(14,7)*Z(47)+BX(14,8)*Z(56)+BX(14,9)*Z(65)+BX(14
                 ,10)*Z(74)+BX(14,11)*Z(83)+BX(14,12)*Z(92)+BX(14,13)*Z(101)+BX(14,14)*
                 Z(110)+BX(14,15)*Z(119)+BX(14,16)*Z(128)+BX(14,17)*Z(137)+BX(14,18)*Z
                 (146)+BX(14,19)*Z(155)+BX(14,20)*S(50))-F3*(AX(14,1)*S(3)+AX (14,2)*
                 Z(2)+AX(14,3)*Z(11)+AX(14,4)*Z(20)+AX(14,5)*Z(29)+AX(14,6)*Z(38)+AX(
                 14,7)*Z(47)+AX(14,8)*Z(56)+AX(14,9)*Z(65)+AX(14,10)*Z(74)+AX(14,11)*Z
                 (83)+AX(14,12)*Z(92)+AX(14,13)*Z(101)+AX(14,14)*Z(110)+AX(14,15)*Z(11
                 9)+AX(14,16)*Z(128)+AX(14,17)*Z(137)+AX(14,18)*Z(146)+AX(14,19)*Z(155
                 )+AX(14,20)*S(50))
ZPRIME(111) = F1*(BY(4,1)*S(36)+SUM(BY(4,2:10)*Z(109:117))+BY(4,11)*S(37))+F2*
                 (BX(14,1)*S(4)+BX(14,2)*Z(3)+BX(14,3)*Z(12)+BX(14,4)*Z(21)+BX(14,5)*Z(
                 30)+BX(14,6)*Z(39)+BX(14,7)*Z(48)+BX(14,8)*Z(57)+BX(14,9)*Z(66)+BX(14
                 ,10)*Z(75)+BX(14,11)*Z(84)+BX(14,12)*Z(93)+BX(14,13)*Z(102)+BX(14,14)*
                 Z(111)+BX(14,15)*Z(120)+BX(14,16)*Z(129)+BX(14,17)*Z(138)+BX(14,18)*Z
                 (147)+BX(14,19)*Z(156)+BX(14,20)*S(51))-F3*(AX(14,1)*S(4)+AX (14,2)*
                 Z(3)+AX(14,3)*Z(12)+AX(14,4)*Z(21)+AX(14,5)*Z(30)+AX(14,6)*Z(39)+AX(
                 14,7)*Z(48)+AX(14,8)*Z(57)+AX(14,9)*Z(66)+AX(14,10)*Z(75)+AX(14,11)*Z
                 (84)+AX(14,12)*Z(93)+AX(14,13)*Z(102)+AX(14,14)*Z(111)+AX(14,15)*Z(12
                 0)+AX(14,16)*Z(129)+AX(14,17)*Z(138)+AX(14,18)*Z(147)+AX(14,19)*Z(156
                 )+AX(14,20)*S(51))
ZPRIME(112) = F1*(BY(5,1)*S(36)+SUM(BY(5,2:10)*Z(109:117))+BY(5,11)*S(37))+F2*
                 (BX(14,1)*S(5)+BX(14,2)*Z(4)+BX(14,3)*Z(13)+BX(14,4)*Z(22)+BX(14,5)*Z(
                 31)+BX(14,6)*Z(40)+BX(14,7)*Z(49)+BX(14,8)*Z(58)+BX(14,9)*Z(67)+BX(14
                 ,10)*Z(76)+BX(14,11)*Z(85)+BX(14,12)*Z(94)+BX(14,13)*Z(103)+BX(14,14)*
                 Z(112)+BX(14,15)*Z(121)+BX(14,16)*Z(130)+BX(14,17)*Z(139)+BX(14,18)*Z
                 (148)+BX(14,19)*Z(157)+BX(14,20)*S(52))-F3*(AX(14,1)*S(5)+AX (14,2)*
                 Z(4)+AX(14,3)*Z(13)+AX(14,4)*Z(22)+AX(14,5)*Z(31)+AX(14,6)*Z(40)+AX(
                 14,7)*Z(49)+AX(14,8)*Z(58)+AX(14,9)*Z(67)+AX(14,10)*Z(76)+AX(14,11)*Z
                 (85)+AX(14,12)*Z(94)+AX(14,13)*Z(103)+AX(14,14)*Z(112)+AX(14,15)*Z(12
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              1)+AX(14,16)*Z(130)+AX(14,17)*Z(139)+AX(14,18)*Z(148)+AX(14,19)*Z(157
              )+AX(14,20)*S(52))
ZPRIME(113) = F1*(BY(6,1)*S(36)+SUM(BY(6,2:10)*Z(109:117))+BY(6,11)*S(37))+F2*
              (BX(14,1)*S(6)+BX(14,2)*Z(5)+BX(14,3)*Z(14)+BX(14,4)*Z(23)+BX(14,5)*Z(
              32)+BX(14,6)*Z(41)+BX(14,7)*Z(50)+BX(14,8)*Z(59)+BX(14,9)*Z(68)+BX(14
              ,10)*Z(77)+BX(14,11)*Z(86)+BX(14,12)*Z(95)+BX(14,13)*Z(104)+BX(14,14)*
              Z(113)+BX(14,15)*Z(122)+BX(14,16)*Z(131)+BX(14,17)*Z(140)+BX(14,18)*Z
              (149)+BX(14,19)*Z(158)+BX(14,20)*S(53))-F3*(AX(14,1)*S(6)+AX(14,2)*
              Z(5)+AX(14,3)*Z(14)+AX(14,4)*Z(23)+AX(14,5)*Z(32)+AX(14,6)*Z(41)+AX(
              14,7)*Z(50)+AX(14,8)*Z(59)+AX(14,9)*Z(68)+AX(14,10)*Z(77)+AX(14,11)*Z
              (86)+AX(14,12)*Z(95)+AX(14,13)*Z(104)+AX(14,14)*Z(113)+AX(14,15)*Z(12
              2)+AX(14,16)*Z(131)+AX(14,17)*Z(140)+AX(14,18)*Z(149)+AX(14,19)*Z(158
              )+AX(14,20)*S(53))
ZPRIME(114) = F1*(BY(7,1)*S(36)+SUM(BY(7,2:10)*Z(109:117))+BY(7,11)*S(37))+F2*
              (BX(14,1)*S(7)+BX(14,2)*Z(6)+BX(14,3)*Z(15)+BX(14,4)*Z(24)+BX(14,5)*Z(
              33)+BX(14,6)*Z(42)+BX(14,7)*Z(51)+BX(14,8)*Z(60)+BX(14,9)*Z(69)+BX(14
              ,10)*Z(78)+BX(14,11)*Z(87)+BX(14,12)*Z(96)+BX(14,13)*Z(105)+BX(14,14)*
              Z(114)+BX(14,15)*Z(123)+BX(14,16)*Z(132)+BX(14,17)*Z(141)+BX(14,18)*Z
              (150)+BX(14,19)*Z(159)+BX(14,20)*S(54))-F3*(AX(14,1)*S(7)+AX (14,2)*
              Z(6)+AX(14,3)*Z(15)+AX(14,4)*Z(24)+AX(14,5)*Z(33)+AX(14,6)*Z(42)+AX(
              14,7)*Z(51)+AX(14,8)*Z(60)+AX(14,9)*Z(69)+AX(14,10)*Z(78)+AX(14,11)*Z
              (87)+AX(14,12)*Z(96)+AX(14,13)*Z(105)+AX(14,14)*Z(114)+AX(14,15)*Z(12
              3)+AX(14,16)*Z(132)+AX(14,17)*Z(141)+AX(14,18)*Z(150)+AX(14,19)*Z(159
              )+AX(14,20)*S(54))
ZPRIME(115) = F1*(BY(8,1)*S(36)+SUM(BY(8,2:10)*Z(109:117))+BY(8,11)*S(37))+F2*
              (BX(14,1)*S(8)+BX(14,2)*Z(7)+BX(14,3)*Z(16)+BX(14,4)*Z(25)+BX(14,5)*Z(
              34)+BX(14,6)*Z(43)+BX(14,7)*Z(52)+BX(14,8)*Z(61)+BX(14,9)*Z(70)+BX(14
              ,10)*Z(79)+BX(14,11)*Z(88)+BX(14,12)*Z(97)+BX(14,13)*Z(106)+BX(14,14)*
              Z(115)+BX(14,15)*Z(124)+BX(14,16)*Z(133)+BX(14,17)*Z(142)+BX(14,18)*Z
              (151)+BX(14,19)*Z(160)+BX(14,20)*S(55))-F3*(AX(14,1)*S(8)+AX (14,2)*
              Z(7)+AX(14,3)*Z(16)+AX(14,4)*Z(25)+AX(14,5)*Z(34)+AX(14,6)*Z(43)+AX(
              14,7)*Z(52)+AX(14,8)*Z(61)+AX(14,9)*Z(70)+AX(14,10)*Z(79)+AX(14,11)*Z
              (88)+AX(14,12)*Z(97)+AX(14,13)*Z(106)+AX(14,14)*Z(115)+AX(14,15)*Z(12
              4)+AX(14,16)*Z(133)+AX(14,17)*Z(142)+AX(14,18)*Z(151)+AX(14,19)*Z(160
              )+AX(14,20)*S(55))
ZPRIME(116) = F1*(BY(9,1)*S(36)+SUM(BY(9,2:10)*Z(109:117))+BY(9,11)*S(37))+F2*
              (BX(14,1)*S(9)+BX(14,2)*Z(8)+BX(14,3)*Z(17)+BX(14,4)*Z(26)+BX(14,5)*Z(
              35)+BX(14,6)*Z(44)+BX(14,7)*Z(53)+BX(14,8)*Z(62)+BX(14,9)*Z(71)+BX(14
              ,10)*Z(80)+BX(14,11)*Z(89)+BX(14,12)*Z(98)+BX(14,13)*Z(107)+BX(14,14)*
              Z(116)+BX(14,15)*Z(125)+BX(14,16)*Z(134)+BX(14,17)*Z(143)+BX(14,18)*Z
              (152)+BX(14,19)*Z(161)+BX(14,20)*S(56))-F3*(AX(14,1)*S(9)+AX (14,2)*
              Z(8)+AX(14,3)*Z(17)+AX(14,4)*Z(26)+AX(14,5)*Z(35)+AX(14,6)*Z(44)+AX(
              14,7)*Z(53)+AX(14,8)*Z(62)+AX(14,9)*Z(71)+AX(14,10)*Z(80)+AX(14,11)*Z
              (89)+AX(14,12)*Z(98)+AX(14,13)*Z(107)+AX(14,14)*Z(116)+AX(14,15)*Z(12
              5)+AX(14,16)*Z(134)+AX(14,17)*Z(143)+AX(14,18)*Z(152)+AX(14,19)*Z(161
              )+AX(14,20)*S(56))
ZPRIME(117) = F1*(BY(10,1)*S(36)+SUM(BY(10,2:10)*Z(109:117))+BY(10,11)*S(37))+F2*
              (BX(14,1)*S(10)+BX(14,2)*Z(9)+BX(14,3)*Z(18)+BX(14,4)*Z(27)+BX(14,5)*Z
              (36)+BX(14,6)*Z(45)+BX(14,7)*Z(54)+BX(14,8)*Z(63)+BX(14,9)*Z(72)+BX(1
              4,10)*Z(81)+BX(14,11)*Z(90)+BX(14,12)*Z(99)+BX(14,13)*Z(108)+BX(14,14)
              *Z(117)+BX(14,15)*Z(126)+BX(14,16)*Z(135)+BX(14,17)*Z(144)+BX(14,18)*
              Z(153)+BX(14,19)*Z(162)+BX(14,20)*S(57))-F3*(AX(14,1)*S(10)+AX (14,2)*
              Z(9)+AX(14,3)*Z(18)+AX(14,4)*Z(27)+AX(14,5)*Z(36)+AX(14,6)*Z(45)+AX(
              14,7)*Z(54)+AX(14,8)*Z(63)+AX(14,9)*Z(72)+AX(14,10)*Z(81)+AX(14,11)*Z
              (90)+AX(14,12)*Z(99)+AX(14,13)*Z(108)+AX(14,14)*Z(117)+AX(14,15)*Z(12
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                    6)+AX(14,16)*Z(135)+AX(14,17)*Z(144)+AX(14,18)*Z(153)+AX(14,19)*Z(162
                    )+AX(14,20)*S(57))
ZPRIME(118)=F1*(BY(2,1)*S(38)+SUM(BY(2,2:10)*Z(118:126))+BY(2,11)*S(39))+F2*(BX
                    (15,1)*S(2)+BX(15,2)*Z(1)+BX(15,3)*Z(10)+BX(15,4)*Z(19)+BX(15,5)*Z(28)+
                    BX(15,6)*Z(37)+BX(15,7)*Z(46)+BX(15,8)*Z(55)+BX(15,9)*Z(64)+BX(15,10)
                    *Z(73)+BX(15,11)*Z(82)+BX(15,12)*Z(91)+BX(15,13)*Z(100)+BX(15,14)*Z(1
                    09)+BX(15,15)*Z(118)+BX(15,16)*Z(127)+BX(15,17)*Z(136)+BX(15,18)*Z(14
                    5)+BX(15,19)*Z(154)+BX(15,20)*S(49))-F3*(AX(15,1)*S(2)+AX (15,2)* Z(1)+
                    AX(15,3)*Z(10)+AX(15,4)*Z(19)+AX(15,5)*Z(28)+AX(15,6)*Z(37)+AX(15,7)*
                    Z(46)+AX(15,8)*Z(55)+AX(15,9)*Z(64)+AX(15,10)*Z(73)+AX(15,11)*Z(82)+
                    AX(15,12)*Z(91)+AX(15,13)*Z(100)+AX(15,14)*Z(109)+AX(15,15)*Z(118)+A
                    X(15,16)*Z(127)+AX(15,17)*Z(136)+AX(15,18)*Z(145)+AX(15,19)*Z(154)+A
                    X(15,20)*S(49))
ZPRIME(119) = F1*(BY(3,1)*S(38)+SUM(BY(3,2:10)*Z(118:126))+BY(3,11)*S(39))+F2*(BX
                    (15,1)*S(3)+BX(15,2)*Z(2)+BX(15,3)*Z(11)+BX(15,4)*Z(20)+BX(15,5)*Z(29)+
                    BX(15,6)*Z(38)+BX(15,7)*Z(47)+BX(15,8)*Z(56)+BX(15,9)*Z(65)+BX(15,10)
                    *Z(74)+BX(15,11)*Z(83)+BX(15,12)*Z(92)+BX(15,13)*Z(101)+BX(15,14)*Z(1
                    10)+BX(15,15)*Z(119)+BX(15,16)*Z(128)+BX(15,17)*Z(137)+BX(15,18)*Z(14
                    6)+BX(15,19)*Z(155)+BX(15,20)*S(50))-F3*(AX(15,1)*S(3)+AX (15,2)* Z(2)
                    +AX(15,3)*Z(11)+AX(15,4)*Z(20)+AX(15,5)*Z(29)+AX(15,6)*Z(38)+AX(15,7)
                    *Z(47)+AX(15,8)*Z(56)+AX(15,9)*Z(65)+AX(15,10)*Z(74)+AX(15,11)*Z(83)+
                    AX(15,12)*Z(92)+AX(15,13)*Z(101)+AX(15,14)*Z(110)+AX(15,15)*Z(119)+A
                    X(15,16)*Z(128)+AX(15,17)*Z(137)+AX(15,18)*Z(146)+AX(15,19)*Z(155)+A
                    X(15,20)*S(50))
ZPRIME(120) = F1*(BY(4,1)*S(38)+SUM(BY(4,2:10)*Z(118:126))+BY(4,11)*S(39))+F2*(BX
                    (15,1)*S(4)+BX(15,2)*Z(3)+BX(15,3)*Z(12)+BX(15,4)*Z(21)+BX(15,5)*Z(30)+
                    BX(15,6)*Z(39)+BX(15,7)*Z(48)+BX(15,8)*Z(57)+BX(15,9)*Z(66)+BX(15,10)
                    *Z(75)+BX(15,11)*Z(84)+BX(15,12)*Z(93)+BX(15,13)*Z(102)+BX(15,14)*Z(1
                    11)+BX(15,15)*Z(120)+BX(15,16)*Z(129)+BX(15,17)*Z(138)+BX(15,18)*Z(14
                    7)+BX(15,19)*Z(156)+BX(15,20)*S(51))-F3*(AX(15,1)*S(4)+AX (15,2)*Z(3)+
                    AX(15,3)*Z(12)+AX(15,4)*Z(21)+AX(15,5)*Z(30)+AX(15,6)*Z(39)+AX(15,7)*
                    Z(48)+AX(15,8)*Z(57)+AX(15,9)*Z(66)+AX(15,10)*Z(75)+AX(15,11)*Z(84)+
                    AX(15,12)*Z(93)+AX(15,13)*Z(102)+AX(15,14)*Z(111)+AX(15,15)*Z(120)+A
                    X(15,16)*Z(129)+AX(15,17)*Z(138)+AX(15,18)*Z(147)+AX(15,19)*Z(156)+A
                    X(15,20)*S(51))
ZPRIME(121) = F1*(BY(5,1)*S(38)+SUM(BY(5,2:10)*Z(118:126))+BY(5,11)*S(39))+F2*(BX
                    (15,1)*S(5)+BX(15,2)*Z(4)+BX(15,3)*Z(13)+BX(15,4)*Z(22)+BX(15,5)*Z(31)+
                    BX(15,6)*Z(40)+BX(15,7)*Z(49)+BX(15,8)*Z(58)+BX(15,9)*Z(67)+BX(15,10)
                    *Z(76)+BX(15,11)*Z(85)+BX(15,12)*Z(94)+BX(15,13)*Z(103)+BX(15,14)*Z(1
                    12)+BX(15,15)*Z(121)+BX(15,16)*Z(130)+BX(15,17)*Z(139)+BX(15,18)*Z(14
                    8)+BX(15,19)*Z(157)+BX(15,20)*S(52))-F3*(AX(15,1)*S(5)+AX (15,2)*Z(4)+
                    AX(15,3)*Z(13)+AX(15,4)*Z(22)+AX(15,5)*Z(31)+AX(15,6)*Z(40)+AX(15,7)*
                    Z(49)+AX(15,8)*Z(58)+AX(15,9)*Z(67)+AX(15,10)*Z(76)+AX(15,11)*Z(85)+
                    AX(15,12)*Z(94)+AX(15,13)*Z(103)+AX(15,14)*Z(112)+AX(15,15)*Z(121)+A
                    X(15,16)*Z(130)+AX(15,17)*Z(139)+AX(15,18)*Z(148)+AX(15,19)*Z(157)+A
                    X(15,20)*S(52))
ZPRIME(122) = F1*(BY(6,1)*S(38)+SUM(BY(6,2:10)*Z(118:126))+BY(6,11)*S(39))+F2* (BX
                    (15,1)*S(6)+BX(15,2)*Z(5)+BX(15,3)*Z(14)+BX(15,4)*Z(23)+BX(15,5)*Z(32)+
                    BX(15,6)*Z(41)+BX(15,7)*Z(50)+BX(15,8)*Z(59)+BX(15,9)*Z(68)+BX(15,10)
                    *Z(77)+BX(15,11)*Z(86)+BX(15,12)*Z(95)+BX(15,13)*Z(104)+BX(15,14)*Z(1
                    13)+BX(15,15)*Z(122)+BX(15,16)*Z(131)+BX(15,17)*Z(140)+BX(15,18)*Z(14
                    9)+BX(15,19)*Z(158)+BX(15,20)*S(53))-F3*(AX(15,1)*S(6)+AX (15,2)* Z(5)+
                    AX(15,3)*Z(14)+AX(15,4)*Z(23)+AX(15,5)*Z(32)+AX(15,6)*Z(41)+AX(15,7)*
                    Z(50)+AX(15,8)*Z(59)+AX(15,9)*Z(68)+AX(15,10)*Z(77)+AX(15,11)*Z(86)+
                    AX(15,12)*Z(95)+AX(15,13)*Z(104)+AX(15,14)*Z(113)+AX(15,15)*Z(122)+A
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                    X(15,16)*Z(131)+AX(15,17)*Z(140)+AX(15,18)*Z(149)+AX(15,19)*Z(158)+A
                    X(15,20)*S(53))
ZPRIME(123) = F1*(BY(7,1)*S(38)+SUM(BY(7,2:10)*Z(118:126))+BY(7,11)*S(39))+F2* (BX
                    (15,1)*S(7)+BX(15,2)*Z(6)+BX(15,3)*Z(15)+BX(15,4)*Z(24)+BX(15,5)*Z(33)+
                    BX(15,6)*Z(42)+BX(15,7)*Z(51)+BX(15,8)*Z(60)+BX(15,9)*Z(69)+BX(15,10)
                    *Z(78)+BX(15,11)*Z(87)+BX(15,12)*Z(96)+BX(15,13)*Z(105)+BX(15,14)*Z(1
                    14)+BX(15,15)*Z(123)+BX(15,16)*Z(132)+BX(15,17)*Z(141)+BX(15,18)*Z(15
                    0)+BX(15,19)*Z(159)+BX(15,20)*S(54))-F3*(AX(15,1)*S(7)+AX (15,2)*Z(6)+
                    AX(15,3)*Z(15)+AX(15,4)*Z(24)+AX(15,5)*Z(33)+AX(15,6)*Z(42)+AX(15,7)*
                    Z(51)+AX(15,8)*Z(60)+AX(15,9)*Z(69)+AX(15,10)*Z(78)+AX(15,11)*Z(87)+
                    AX(15,12)*Z(96)+AX(15,13)*Z(105)+AX(15,14)*Z(114)+AX(15,15)*Z(123)+A
                    X(15,16)*Z(132)+AX(15,17)*Z(141)+AX(15,18)*Z(150)+AX(15,19)*Z(159)+A
                    X(15,20)*S(54))
ZPRIME(124) = F1*(BY(8,1)*S(38)+SUM(BY(8,2:10)*Z(118:126))+BY(8,11)*S(39))+F2* (BX
                    (15,1)*S(8)+BX(15,2)*Z(7)+BX(15,3)*Z(16)+BX(15,4)*Z(25)+BX(15,5)*Z(34)+
                    BX(15,6)*Z(43)+BX(15,7)*Z(52)+BX(15,8)*Z(61)+BX(15,9)*Z(70)+BX(15,10)
                    *Z(79)+BX(15,11)*Z(88)+BX(15,12)*Z(97)+BX(15,13)*Z(106)+BX(15,14)*Z(1
                    15)+BX(15,15)*Z(124)+BX(15,16)*Z(133)+BX(15,17)*Z(142)+BX(15,18)*Z(15
                    1)+BX(15,19)*Z(160)+BX(15,20)*S(55))-F3*(AX(15,1)*S(8)+AX (15,2)*Z(7)+
                    AX(15,3)*Z(16)+AX(15,4)*Z(25)+AX(15,5)*Z(34)+AX(15,6)*Z(43)+AX(15,7)*
                    Z(52)+AX(15,8)*Z(61)+AX(15,9)*Z(70)+AX(15,10)*Z(79)+AX(15,11)*Z(88)+
                    AX(15,12)*Z(97)+AX(15,13)*Z(106)+AX(15,14)*Z(115)+AX(15,15)*Z(124)+A
                    X(15,16)*Z(133)+AX(15,17)*Z(142)+AX(15,18)*Z(151)+AX(15,19)*Z(160)+A
                    X(15,20)*S(55))
ZPRIME(125) = F1*(BY(9,1)*S(38)+SUM(BY(9,2:10)*Z(118:126))+BY(9,11)*S(39))+F2* (BX
                    (15,1)*S(9)+BX(15,2)*Z(8)+BX(15,3)*Z(17)+BX(15,4)*Z(26)+BX(15,5)*Z(35)+
                    BX(15,6)*Z(44)+BX(15,7)*Z(53)+BX(15,8)*Z(62)+BX(15,9)*Z(71)+BX(15,10)
                    *Z(80)+BX(15,11)*Z(89)+BX(15,12)*Z(98)+BX(15,13)*Z(107)+BX(15,14)*Z(1
                    16)+BX(15,15)*Z(125)+BX(15,16)*Z(134)+BX(15,17)*Z(143)+BX(15,18)*Z(15
                    2)+BX(15,19)*Z(161)+BX(15,20)*S(56))-F3*(AX(15,1)*S(9)+AX (15,2)*Z(8)+
                    AX(15,3)*Z(17)+AX(15,4)*Z(26)+AX(15,5)*Z(35)+AX(15,6)*Z(44)+AX(15,7)*
                    Z(53)+AX(15,8)*Z(62)+AX(15,9)*Z(71)+AX(15,10)*Z(80)+AX(15,11)*Z(89)+
                    AX(15,12)*Z(98)+AX(15,13)*Z(107)+AX(15,14)*Z(116)+AX(15,15)*Z(125)+A
                    X(15,16)*Z(134)+AX(15,17)*Z(143)+AX(15,18)*Z(152)+AX(15,19)*Z(161)+A
                    X(15,20)*S(56))
ZPRIME(126) = F1*(BY(10,1)*S(38)+SUM(BY(10,2:10)*Z(118:126))+BY(10,11)*S(39))+F2*
                    (BX(15,1)*S(10)+BX(15,2)*Z(9)+BX(15,3)*Z(18)+BX(15,4)*Z(27)+BX(15,5)*Z
                    (36)+BX(15,6)*Z(45)+BX(15,7)*Z(54)+BX(15,8)*Z(63)+BX(15,9)*Z(72)+BX(1
                    5,10)*Z(81)+BX(15,11)*Z(90)+BX(15,12)*Z(99)+BX(15,13)*Z(108)+BX(15,14)
                    *Z(117)+BX(15,15)*Z(126)+BX(15,16)*Z(135)+BX(15,17)*Z(144)+BX(15,18)*
                    Z(153)+BX(15,19)*Z(162)+BX(15,20)*S(57))-F3*(AX(15,1)*S(10)+AX (15,2)*
                    Z(9)+AX(15,3)*Z(18)+AX(15,4)*Z(27)+AX(15,5)*Z(36)+AX(15,6)*Z(45)+AX(
                    15,7)*Z(54)+AX(15,8)*Z(63)+AX(15,9)*Z(72)+AX(15,10)*Z(81)+AX(15,11)*Z
                    (90)+AX(15,12)*Z(99)+AX(15,13)*Z(108)+AX(15,14)*Z(117)+AX(15,15)*Z(12
                    6)+AX(15,16)*Z(135)+AX(15,17)*Z(144)+AX(15,18)*Z(153)+AX(15,19)*Z(162
                    )+AX(15,20)*S(57))
ZPRIME(127) = F1*(BY(2,1)*S(40)+SUM(BY(2,2:10)*Z(127:135))+BY(2,11)*S(41))+F2* (BX
                    (16,1)*S(2)+BX(16,2)*Z(1)+BX(16,3)*Z(10)+BX(16,4)*Z(19)+BX(16,5)*Z(28)+
                    BX(16,6)*Z(37)+BX(16,7)*Z(46)+BX(16,8)*Z(55)+BX(16,9)*Z(64)+BX(16,10)
                    *Z(73)+BX(16,11)*Z(82)+BX(16,12)*Z(91)+BX(16,13)*Z(100)+BX(16,14)*Z(1
                    09)+BX(16,15)*Z(118)+BX(16,16)*Z(127)+BX(16,17)*Z(136)+BX(16,18)*Z(14
                    5)+BX(16,19)*Z(154)+BX(16,20)*S(49))-F3*(AX(16,1)*S(2)+AX (16,2)*Z(1)+
                    AX(16,3)*Z(10)+AX(16,4)*Z(19)+AX(16,5)*Z(28)+AX(16,6)*Z(37)+AX(16,7)*
                    Z(46)+AX(16,8)*Z(55)+AX(16,9)*Z(64)+AX(16,10)*Z(73)+AX(16,11)*Z(82)+
                    AX(16,12)*Z(91)+AX(16,13)*Z(100)+AX(16,14)*Z(109)+AX(16,15)*Z(118)+A
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                 X(16,16)*Z(127)+AX(16,17)*Z(136)+AX(16,18)*Z(145)+AX(16,19)*Z(154)+A
                 X(16,20)*S(49))
ZPRIME(128) = F1*(BY(3,1)*S(40)+SUM(BY(3,2:10)*Z(127:135))+BY(3,11)*S(41))+F2* (BX
                 (16,1)*S(3)+BX(16,2)*Z(2)+BX(16,3)*Z(11)+BX(16,4)*Z(20)+BX(16,5)*Z(29)+
                 BX(16,6)*Z(38)+BX(16,7)*Z(47)+BX(16,8)*Z(56)+BX(16,9)*Z(65)+BX(16,10)
                 *Z(74)+BX(16,11)*Z(83)+BX(16,12)*Z(92)+BX(16,13)*Z(101)+BX(16,14)*Z(1
                 10)+BX(16,15)*Z(119)+BX(16,16)*Z(128)+BX(16,17)*Z(137)+BX(16,18)*Z(14
                 6)+BX(16,19)*Z(155)+BX(16,20)*S(50))-F3*(AX(16,1)*S(3)+AX (16,2)*Z(2)+
                 AX(16,3)*Z(11)+AX(16,4)*Z(20)+AX(16,5)*Z(29)+AX(16,6)*Z(38)+AX(16,7)*
                 Z(47)+AX(16,8)*Z(56)+AX(16,9)*Z(65)+AX(16,10)*Z(74)+AX(16,11)*Z(83)+
                 AX(16,12)*Z(92)+AX(16,13)*Z(101)+AX(16,14)*Z(110)+AX(16,15)*Z(119)+A
                 X(16,16)*Z(128)+AX(16,17)*Z(137)+AX(16,18)*Z(146)+AX(16,19)*Z(155)+A
                 X(16,20)*S(50))
ZPRIME(129) = F1*(BY(4,1)*S(40)+SUM(BY(4,2:10)*Z(127:135))+BY(4,11)*S(41))+F2* (BX
                 (16,1)*S(4)+BX(16,2)*Z(3)+BX(16,3)*Z(12)+BX(16,4)*Z(21)+BX(16,5)*Z(30)+
                 BX(16,6)*Z(39)+BX(16,7)*Z(48)+BX(16,8)*Z(57)+BX(16,9)*Z(66)+BX(16,10)
                 *Z(75)+BX(16,11)*Z(84)+BX(16,12)*Z(93)+BX(16,13)*Z(102)+BX(16,14)*Z(1
                 11)+BX(16,15)*Z(120)+BX(16,16)*Z(129)+BX(16,17)*Z(138)+BX(16,18)*Z(14
                 7)+BX(16,19)*Z(156)+BX(16,20)*S(51))-F3*(AX(16,1)*S(4)+AX (16,2)*Z(3)+
                 AX(16,3)*Z(12)+AX(16,4)*Z(21)+AX(16,5)*Z(30)+AX(16,6)*Z(39)+AX(16,7)*
                 Z(48)+AX(16,8)*Z(57)+AX(16,9)*Z(66)+AX(16,10)*Z(75)+AX(16,11)*Z(84)+
                 AX(16,12)*Z(93)+AX(16,13)*Z(102)+AX(16,14)*Z(111)+AX(16,15)*Z(120)+A
                 X(16,16)*Z(129)+AX(16,17)*Z(138)+AX(16,18)*Z(147)+AX(16,19)*Z(156)+A
                 X(16,20)*S(51))
ZPRIME(130) = F1*(BY(5,1)*S(40)+SUM(BY(5,2:10)*Z(127:135))+BY(5,11)*S(41))+F2* (BX
                 (16,1)*S(5)+BX(16,2)*Z(4)+BX(16,3)*Z(13)+BX(16,4)*Z(22)+BX(16,5)*Z(31)+
                 BX(16,6)*Z(40)+BX(16,7)*Z(49)+BX(16,8)*Z(58)+BX(16,9)*Z(67)+BX(16,10)
                 *Z(76)+BX(16,11)*Z(85)+BX(16,12)*Z(94)+BX(16,13)*Z(103)+BX(16,14)*Z(1
                 12)+BX(16,15)*Z(121)+BX(16,16)*Z(130)+BX(16,17)*Z(139)+BX(16,18)*Z(14
                 8)+BX(16,19)*Z(157)+BX(16,20)*S(52))-F3*(AX(16,1)*S(5)+AX (16,2)*Z(4)+
                 AX(16,3)*Z(13)+AX(16,4)*Z(22)+AX(16,5)*Z(31)+AX(16,6)*Z(40)+AX(16,7)*
                 Z(49)+AX(16,8)*Z(58)+AX(16,9)*Z(67)+AX(16,10)*Z(76)+AX(16,11)*Z(85)+
                 AX(16,12)*Z(94)+AX(16,13)*Z(103)+AX(16,14)*Z(112)+AX(16,15)*Z(121)+A
                 X(16,16)*Z(130)+AX(16,17)*Z(139)+AX(16,18)*Z(148)+AX(16,19)*Z(157)+A
                 X(16,20)*S(52))
ZPRIME(131) = F1*(BY(6,1)*S(40)+SUM(BY(6,2:10)*Z(127:135))+BY(6,11)*S(41))+F2* (BX
                 (16,1)*S(6)+BX(16,2)*Z(5)+BX(16,3)*Z(14)+BX(16,4)*Z(23)+BX(16,5)*Z(32)+
                 BX(16,6)*Z(41)+BX(16,7)*Z(50)+BX(16,8)*Z(59)+BX(16,9)*Z(68)+BX(16,10)
                 *Z(77)+BX(16,11)*Z(86)+BX(16,12)*Z(95)+BX(16,13)*Z(104)+BX(16,14)*Z(1
                 13)+BX(16,15)*Z(122)+BX(16,16)*Z(131)+BX(16,17)*Z(140)+BX(16,18)*Z(14
                 9)+BX(16,19)*Z(158)+BX(16,20)*S(53))-F3*(AX(16,1)*S(6)+AX (16,2)*Z(5)+
                 AX(16,3)*Z(14)+AX(16,4)*Z(23)+AX(16,5)*Z(32)+AX(16,6)*Z(41)+AX(16,7)*
                 Z(50)+AX(16,8)*Z(59)+AX(16,9)*Z(68)+AX(16,10)*Z(77)+AX(16,11)*Z(86)+
                 AX(16,12)*Z(95)+AX(16,13)*Z(104)+AX(16,14)*Z(113)+AX(16,15)*Z(122)+A
                 X(16,16)*Z(131)+AX(16,17)*Z(140)+AX(16,18)*Z(149)+AX(16,19)*Z(158)+A
                 X(16,20)*S(53))
ZPRIME(132) = F1*(BY(7,1)*S(40)+SUM(BY(7,2:10)*Z(127:135))+BY(7,11)*S(41))+F2* (BX
                 (16,1)*S(7)+BX(16,2)*Z(6)+BX(16,3)*Z(15)+BX(16,4)*Z(24)+BX(16,5)*Z(33)+
                 BX(16,6)*Z(42)+BX(16,7)*Z(51)+BX(16,8)*Z(60)+BX(16,9)*Z(69)+BX(16,10)
                 *Z(78)+BX(16,11)*Z(87)+BX(16,12)*Z(96)+BX(16,13)*Z(105)+BX(16,14)*Z(1
                 14)+BX(16,15)*Z(123)+BX(16,16)*Z(132)+BX(16,17)*Z(141)+BX(16,18)*Z(15
                 0)+BX(16,19)*Z(159)+BX(16,20)*S(54))-F3*(AX(16,1)*S(7)+AX (16,2)*Z(6)+
                 AX(16,3)*Z(15)+AX(16,4)*Z(24)+AX(16,5)*Z(33)+AX(16,6)*Z(42)+AX(16,7)*
                 Z(51)+AX(16,8)*Z(60)+AX(16,9)*Z(69)+AX(16,10)*Z(78)+AX(16,11)*Z(87)+
                 AX(16,12)*Z(96)+AX(16,13)*Z(105)+AX(16,14)*Z(114)+AX(16,15)*Z(123)+A
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X(16,16)*Z(132)+AX(16,17)*Z(141)+AX(16,18)*Z(150)+AX(16,19)*Z(159)+A
X(16,20)*S(54))
ZPRIME(133) = F1*(BY(8,1)*S(40)+SUM(BY(8,2:10)*Z(127:135))+BY(8,11)*S(41))+F2* (BX
(16,1)*S(8)+BX(16,2)*Z(7)+BX(16,3)*Z(16)+BX(16,4)*Z(25)+BX(16,5)*Z(34)+
BX(16,6)*Z(43)+BX(16,7)*Z(52)+BX(16,8)*Z(61)+BX(16,9)*Z(70)+BX(16,10)
*Z(79)+BX(16,11)*Z(88)+BX(16,12)*Z(97)+BX(16,13)*Z(106)+BX(16,14)*Z(1
15)+BX(16,15)*Z(124)+BX(16,16)*Z(133)+BX(16,17)*Z(142)+BX(16,18)*Z(15
1)+BX(16,19)*Z(160)+BX(16,20)*S(55))-F3*(AX(16,1)*S(8)+AX (16,2)*Z(7)+
AX(16,3)*Z(16)+AX(16,4)*Z(25)+AX(16,5)*Z(34)+AX(16,6)*Z(43)+AX(16,7)*
Z(52)+AX(16,8)*Z(61)+AX(16,9)*Z(70)+AX(16,10)*Z(79)+AX(16,11)*Z(88)+
AX(16,12)*Z(97)+AX(16,13)*Z(106)+AX(16,14)*Z(115)+AX(16,15)*Z(124)+A
X(16,16)*Z(133)+AX(16,17)*Z(142)+AX(16,18)*Z(151)+AX(16,19)*Z(160)+A
X(16,20)*S(55))
ZPRIME(134) = F1*(BY(9,1)*S(40)+SUM(BY(9,2:10)*Z(127:135))+BY(9,11)*S(41))+F2* (BX
(16,1)*S(9)+BX(16,2)*Z(8)+BX(16,3)*Z(17)+BX(16,4)*Z(26)+BX(16,5)*Z(35)+
BX(16,6)*Z(44)+BX(16,7)*Z(53)+BX(16,8)*Z(62)+BX(16,9)*Z(71)+BX(16,10)
*Z(80)+BX(16,11)*Z(89)+BX(16,12)*Z(98)+BX(16,13)*Z(107)+BX(16,14)*Z(1
16)+BX(16,15)*Z(125)+BX(16,16)*Z(134)+BX(16,17)*Z(143)+BX(16,18)*Z(15
2)+BX(16,19)*Z(161)+BX(16,20)*S(56))-F3*(AX(16,1)*S(9)+AX (16,2)*Z(8)+
AX(16,3)*Z(17)+AX(16,4)*Z(26)+AX(16,5)*Z(35)+AX(16,6)*Z(44)+AX(16,7)*
Z(53)+AX(16,8)*Z(62)+AX(16,9)*Z(71)+AX(16,10)*Z(80)+AX(16,11)*Z(89)+
AX(16,12)*Z(98)+AX(16,13)*Z(107)+AX(16,14)*Z(116)+AX(16,15)*Z(125)+A
X(16,16)*Z(134)+AX(16,17)*Z(143)+AX(16,18)*Z(152)+AX(16,19)*Z(161)+A
X(16,20)*S(56))
ZPRIME(135) = F1*(BY(10,1)*S(40)+SUM(BY(10,2:10)*Z(127:135))+BY(10,11)*S(41))+F2*
(BX(16,1)*S(10)+BX(16,2)*Z(9)+BX(16,3)*Z(18)+BX(16,4)*Z(27)+BX(16,5)*Z
(36)+BX(16,6)*Z(45)+BX(16,7)*Z(54)+BX(16,8)*Z(63)+BX(16,9)*Z(72)+BX(1
6,10)*Z(81)+BX(16,11)*Z(90)+BX(16,12)*Z(99)+BX(16,13)*Z(108)+BX(16,14)
*Z(117)+BX(16,15)*Z(126)+BX(16,16)*Z(135)+BX(16,17)*Z(144)+BX(16,18)*
Z(153)+BX(16,19)*Z(162)+BX(16,20)*S(57))-F3*(AX(16,1)*S(10)+AX (16,2)*
Z(9)+AX(16,3)*Z(18)+AX(16,4)*Z(27)+AX(16,5)*Z(36)+AX(16,6)*Z(45)+AX(
16,7)*Z(54)+AX(16,8)*Z(63)+AX(16,9)*Z(72)+AX(16,10)*Z(81)+AX(16,11)*Z
(90)+AX(16,12)*Z(99)+AX(16,13)*Z(108)+AX(16,14)*Z(117)+AX(16,15)*Z(12
6)+AX(16,16)*Z(135)+AX(16,17)*Z(144)+AX(16,18)*Z(153)+AX(16,19)*Z(162
)+AX(16,20)*S(57))
ZPRIME(136) = F1*(BY(2,1)*S(42)+SUM(BY(2,2:10)*Z(136:144))+BY(2,11)*S(43))+F2* (BX
(17,1)*S(2)+BX(17,2)*Z(1)+BX(17,3)*Z(10)+BX(17,4)*Z(19)+BX(17,5)*Z(28)+
BX(17,6)*Z(37)+BX(17,7)*Z(46)+BX(17,8)*Z(55)+BX(17,9)*Z(64)+BX(17,10)
*Z(73)+BX(17,11)*Z(82)+BX(17,12)*Z(91)+BX(17,13)*Z(100)+BX(17,14)*Z(1
09)+BX(17,15)*Z(118)+BX(17,16)*Z(127)+BX(17,17)*Z(136)+BX(17,18)*Z(14
5)+BX(17,19)*Z(154)+BX(17,20)*S(49))-F3*(AX(17,1)*S(2)+AX (17,2)*Z(1)+
AX(17,3)*Z(10)+AX(16,4)*Z(19)+AX(17,5)*Z(28)+AX(17,6)*Z(37)+AX(17,7)*
Z(46)+AX(17,8)*Z(55)+AX(17,9)*Z(64)+AX(17,10)*Z(73)+AX(17,11)*Z(82)+
AX(17,12)*Z(91)+AX(17,13)*Z(100)+AX(17,14)*Z(109)+AX(17,15)*Z(118)+A
X(17,16)*Z(127)+AX(17,17)*Z(136)+AX(17,18)*Z(145)+AX(17,19)*Z(154)+A
X(17,20)*S(49))
ZPRIME(137) = F1*(BY(3,1)*S(42)+SUM(BY(3,2:10)*Z(136:144))+BY(3,11)*S(43))+F2* (BX
(17,1)*S(3)+BX(17,2)*Z(2)+BX(17,3)*Z(11)+BX(17,4)*Z(20)+BX(17,5)*Z(29)+
BX(17,6)*Z(38)+BX(17,7)*Z(47)+BX(17,8)*Z(56)+BX(17,9)*Z(65)+BX(17,10)
*Z(74)+BX(17,11)*Z(83)+BX(17,12)*Z(92)+BX(17,13)*Z(101)+BX(17,14)*Z(1
10)+BX(17,15)*Z(119)+BX(17,16)*Z(128)+BX(17,17)*Z(137)+BX(17,18)*Z(14
6)+BX(17,19)*Z(155)+BX(17,20)*S(50))-F3*(AX(17,1)*S(3)+AX (17,2)*Z(2)+
AX(17,3)*Z(11)+AX(16,4)*Z(20)+AX(17,5)*Z(29)+AX(17,6)*Z(38)+AX(17,7)*
Z(47)+AX(17,8)*Z(56)+AX(17,9)*Z(65)+AX(17,10)*Z(74)+AX(17,11)*Z(83)+
AX(17,12)*Z(92)+AX(17,13)*Z(101)+AX(17,14)*Z(110)+AX(17,15)*Z(119)+A
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X(17,16)*Z(128)+AX(17,17)*Z(137)+AX(17,18)*Z(146)+AX(17,19)*Z(155)+A
X(17,20)*S(50))

ZPRIME(138) = F1*(BY(4,1)*S(42)+SUM(BY(4,2:10)*Z(136:144))+BY(4,11)*S(43))+F2* (BX
(17,1)*S(4)+BX(17,2)*Z(3)+BX(17,3)*Z(12)+BX(17,4)*Z(21)+BX(17,5)*Z(30)+
BX(17,6)*Z(39)+BX(17,7)*Z(48)+BX(17,8)*Z(57)+BX(17,9)*Z(66)+BX(17,10)
*Z(75)+BX(17,11)*Z(84)+BX(17,12)*Z(93)+BX(17,13)*Z(102)+BX(17,14)*Z(1
11)+BX(17,15)*Z(120)+BX(17,16)*Z(129)+BX(17,17)*Z(138)+BX(17,18)*Z(14
7)+BX(17,19)*Z(156)+BX(17,20)*S(51))-F3*(AX(17,1)*S(4)+AX (17,2)*Z(3)+
AX(17,3)*Z(12)+AX(16,4)*Z(21)+AX(17,5)*Z(30)+AX(17,6)*Z(39)+AX(17,7)*
Z(48)+AX(17,8)*Z(57)+AX(17,9)*Z(66)+AX(17,10)*Z(75)+AX(17,11)*Z(84)+
AX(17,12)*Z(93)+AX(17,13)*Z(102)+AX(17,14)*Z(111)+AX(17,15)*Z(120)+A
X(17,16)*Z(129)+AX(17,17)*Z(138)+AX(17,18)*Z(147)+AX(17,19)*Z(156)+A
X(17,20)*S(51))

ZPRIME(139) = F1*(BY(5,1)*S(42)+SUM(BY(5,2:10)*Z(136:144))+BY(5,11)*S(43))+F2* (BX
(17,1)*S(5)+BX(17,2)*Z(4)+BX(17,3)*Z(13)+BX(17,4)*Z(22)+BX(17,5)*Z(31)+
BX(17,6)*Z(40)+BX(17,7)*Z(49)+BX(17,8)*Z(58)+BX(17,9)*Z(67)+BX(17,10)
*Z(76)+BX(17,11)*Z(85)+BX(17,12)*Z(94)+BX(17,13)*Z(103)+BX(17,14)*Z(1
12)+BX(17,15)*Z(121)+BX(17,16)*Z(130)+BX(17,17)*Z(139)+BX(17,18)*Z(14
8)+BX(17,19)*Z(157)+BX(17,20)*S(52))-F3*(AX(17,1)*S(5)+AX (17,2)*Z(4)+
AX(17,3)*Z(13)+AX(16,4)*Z(22)+AX(17,5)*Z(31)+AX(17,6)*Z(40)+AX(17,7)*
Z(49)+AX(17,8)*Z(58)+AX(17,9)*Z(67)+AX(17,10)*Z(76)+AX(17,11)*Z(85)+
AX(17,12)*Z(94)+AX(17,13)*Z(103)+AX(17,14)*Z(112)+AX(17,15)*Z(121)+A
X(17,16)*Z(130)+AX(17,17)*Z(139)+AX(17,18)*Z(148)+AX(17,19)*Z(157)+A
X(17,20)*S(52))

ZPRIME(140) = F1*(BY(6,1)*S(42)+SUM(BY(6,2:10)*Z(136:144))+BY(6,11)*S(43))+F2* (BX
(17,1)*S(6)+BX(17,2)*Z(5)+BX(17,3)*Z(14)+BX(17,4)*Z(23)+BX(17,5)*Z(32)+
BX(17,6)*Z(41)+BX(17,7)*Z(50)+BX(17,8)*Z(59)+BX(17,9)*Z(68)+BX(17,10)
*Z(77)+BX(17,11)*Z(86)+BX(17,12)*Z(95)+BX(17,13)*Z(104)+BX(17,14)*Z(1
13)+BX(17,15)*Z(122)+BX(17,16)*Z(131)+BX(17,17)*Z(140)+BX(17,18)*Z(14
9)+BX(17,19)*Z(158)+BX(17,20)*S(53))-F3*(AX(17,1)*S(6)+AX (17,2)*Z(5)+
AX(17,3)*Z(14)+AX(16,4)*Z(23)+AX(17,5)*Z(32)+AX(17,6)*Z(41)+AX(17,7)*
Z(50)+AX(17,8)*Z(59)+AX(17,9)*Z(68)+AX(17,10)*Z(77)+AX(17,11)*Z(86)+
AX(17,12)*Z(95)+AX(17,13)*Z(104)+AX(17,14)*Z(113)+AX(17,15)*Z(122)+A
X(17,16)*Z(131)+AX(17,17)*Z(140)+AX(17,18)*Z(149)+AX(17,19)*Z(158)+A
X(17,20)*S(53))

ZPRIME(141) = F1*(BY(7,1)*S(42)+SUM(BY(7,2:10)*Z(136:144))+BY(7,11)*S(43))+F2* (BX
(17,1)*S(7)+BX(17,2)*Z(6)+BX(17,3)*Z(15)+BX(17,4)*Z(24)+BX(17,5)*Z(33)+
BX(17,6)*Z(42)+BX(17,7)*Z(51)+BX(17,8)*Z(60)+BX(17,9)*Z(69)+BX(17,10)
*Z(78)+BX(17,11)*Z(87)+BX(17,12)*Z(96)+BX(17,13)*Z(105)+BX(17,14)*Z(1
14)+BX(17,15)*Z(123)+BX(17,16)*Z(132)+BX(17,17)*Z(141)+BX(17,18)*Z(15
0)+BX(17,19)*Z(159)+BX(17,20)*S(54))-F3*(AX(17,1)*S(7)+AX (17,2)*Z(6)+
AX(17,3)*Z(15)+AX(16,4)*Z(24)+AX(17,5)*Z(33)+AX(17,6)*Z(42)+AX(17,7)*
Z(51)+AX(17,8)*Z(60)+AX(17,9)*Z(69)+AX(17,10)*Z(78)+AX(17,11)*Z(87)+
AX(17,12)*Z(96)+AX(17,13)*Z(105)+AX(17,14)*Z(114)+AX(17,15)*Z(123)+A
X(17,16)*Z(132)+AX(17,17)*Z(141)+AX(17,18)*Z(150)+AX(17,19)*Z(159)+A
X(17,20)*S(54))

ZPRIME(142) = F1*(BY(8,1)*S(42)+SUM(BY(8,2:10)*Z(136:144))+BY(8,11)*S(43))+F2* (BX
(17,1)*S(8)+BX(17,2)*Z(7)+BX(17,3)*Z(16)+BX(17,4)*Z(25)+BX(17,5)*Z(34)+
BX(17,6)*Z(43)+BX(17,7)*Z(52)+BX(17,8)*Z(61)+BX(17,9)*Z(70)+BX(17,10)
*Z(79)+BX(17,11)*Z(88)+BX(17,12)*Z(97)+BX(17,13)*Z(106)+BX(17,14)*Z(1
15)+BX(17,15)*Z(124)+BX(17,16)*Z(133)+BX(17,17)*Z(142)+BX(17,18)*Z(15
1)+BX(17,19)*Z(160)+BX(17,20)*S(55))-F3*(AX(17,1)*S(8)+AX (17,2)*Z(7)+
AX(17,3)*Z(16)+AX(16,4)*Z(25)+AX(17,5)*Z(34)+AX(17,6)*Z(43)+AX(17,7)*
Z(52)+AX(17,8)*Z(61)+AX(17,9)*Z(70)+AX(17,10)*Z(79)+AX(17,11)*Z(88)+
AX(17,12)*Z(97)+AX(17,13)*Z(106)+AX(17,14)*Z(115)+AX(17,15)*Z(124)+A

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                X(17,16)*Z(133)+AX(17,17)*Z(142)+AX(17,18)*Z(151)+AX(17,19)*Z(160)+A
                X(17,20)*S(55))
ZPRIME(143) = F1*(BY(9,1)*S(42)+SUM(BY(9,2:10)*Z(136:144))+BY(9,11)*S(43))+F2* (BX
                (17,1)*S(9)+BX(17,2)*Z(8)+BX(17,3)*Z(17)+BX(17,4)*Z(26)+BX(17,5)*Z(35)+
                BX(17,6)*Z(44)+BX(17,7)*Z(53)+BX(17,8)*Z(62)+BX(17,9)*Z(71)+BX(17,10)
                *Z(80)+BX(17,11)*Z(89)+BX(17,12)*Z(98)+BX(17,13)*Z(107)+BX(17,14)*Z(1
                16)+BX(17,15)*Z(125)+BX(17,16)*Z(134)+BX(17,17)*Z(143)+BX(17,18)*Z(15
                2)+BX(17,19)*Z(161)+BX(17,20)*S(56))-F3*(AX(17,1)*S(9)+AX (17,2)*Z(8)+
                AX(17,3)*Z(17)+AX(16,4)*Z(26)+AX(17,5)*Z(35)+AX(17,6)*Z(44)+AX(17,7)*
                Z(53)+AX(17,8)*Z(62)+AX(17,9)*Z(71)+AX(17,10)*Z(80)+AX(17,11)*Z(89)+
                AX(17,12)*Z(98)+AX(17,13)*Z(107)+AX(17,14)*Z(116)+AX(17,15)*Z(125)+A
                X(17,16)*Z(134)+AX(17,17)*Z(143)+AX(17,18)*Z(152)+AX(17,19)*Z(161)+A
                X(17,20)*S(56))
ZPRIME(144) = F1*(BY(10,1)*S(42)+SUM(BY(10,2:10)*Z(136:144))+BY(10,11)*S(43))+F2*
                (BX(17,1)*S(10)+BX(17,2)*Z(9)+BX(17,3)*Z(18)+BX(17,4)*Z(27)+BX(17,5)*Z
                (36)+BX(17,6)*Z(45)+BX(17,7)*Z(54)+BX(17,8)*Z(63)+BX(17,9)*Z(72)+BX(1
                7,10)*Z(81)+BX(17,11)*Z(90)+BX(17,12)*Z(99)+BX(17,13)*Z(108)+BX(17,14)
                *Z(117)+BX(17,15)*Z(126)+BX(17,16)*Z(135)+BX(17,17)*Z(144)+BX(17,18)*
                Z(153)+BX(17,19)*Z(162)+BX(17,20)*S(57))-F3*(AX(17,1)*S(10)+AX (17,2)*
                Z(9)+AX(17,3)*Z(18)+AX(16,4)*Z(27)+AX(17,5)*Z(36)+AX(17,6)*Z(45)+AX(
                17,7)*Z(54)+AX(17,8)*Z(63)+AX(17,9)*Z(72)+AX(17,10)*Z(81)+AX(17,11)*Z
                (90)+AX(17,12)*Z(99)+AX(17,13)*Z(108)+AX(17,14)*Z(117)+AX(17,15)*Z(12
                6)+AX(17,16)*Z(135)+AX(17,17)*Z(144)+AX(17,18)*Z(153)+AX(17,19)*Z(162
                )+AX(17,20)*S(57))
ZPRIME(145) = F1*(BY(2,1)*S(44)+SUM(BY(2,2:10)*Z(145:153))+BY(2,11)*S(45))+F2* (BX
                (18,1)*S(2)+BX(18,2)*Z(1)+BX(18,3)*Z(10)+BX(18,4)*Z(19)+BX(18,5)*Z(28)+
                BX(18,6)*Z(37)+BX(18,7)*Z(46)+BX(18,8)*Z(55)+BX(18,9)*Z(64)+BX(18,10)
                *Z(73)+BX(18,11)*Z(82)+BX(18,12)*Z(91)+BX(18,13)*Z(100)+BX(18,14)*Z(1
                09)+BX(18,15)*Z(118)+BX(18,16)*Z(127)+BX(18,17)*Z(136)+BX(18,18)*Z(14
                5)+BX(18,19)*Z(154)+BX(18,20)*S(49))-F3*(AX(18,1)*S(2)+AX (18,2)*Z(1)+
                AX(18,3)*Z(10)+AX(18,4)*Z(19)+AX(18,5)*Z(28)+AX(18,6)*Z(37)+AX(18,7)*
                Z(46)+AX(18,8)*Z(55)+AX(18,9)*Z(64)+AX(18,10)*Z(73)+AX(18,11)*Z(82)+
                AX(18,12)*Z(91)+AX(18,13)*Z(100)+AX(18,14)*Z(109)+AX(18,15)*Z(118)+A
                X(18,16)*Z(127)+AX(18,17)*Z(136)+AX(18,18)*Z(145)+AX(18,19)*Z(154)+A
                X(18,20)*S(49))
ZPRIME(146) = F1*(BY(3,1)*S(44)+SUM(BY(3,2:10)*Z(145:153))+BY(3,11)*S(45))+F2* (BX
                (18,1)*S(3)+BX(18,2)*Z(2)+BX(18,3)*Z(11)+BX(18,4)*Z(20)+BX(18,5)*Z(29)+
                BX(18,6)*Z(38)+BX(18,7)*Z(47)+BX(18,8)*Z(56)+BX(18,9)*Z(65)+BX(18,10)
                *Z(74)+BX(18,11)*Z(83)+BX(18,12)*Z(92)+BX(18,13)*Z(101)+BX(18,14)*Z(1
                10)+BX(18,15)*Z(119)+BX(18,16)*Z(128)+BX(18,17)*Z(137)+BX(18,18)*Z(14
                6)+BX(18,19)*Z(155)+BX(18,20)*S(50))-F3*(AX(18,1)*S(3)+AX (18,2)*Z(2)+
                AX(18,3)*Z(11)+AX(18,4)*Z(20)+AX(18,5)*Z(29)+AX(18,6)*Z(38)+AX(18,7)*
                Z(47)+AX(18,8)*Z(56)+AX(18,9)*Z(65)+AX(18,10)*Z(74)+AX(18,11)*Z(83)+
                AX(18,12)*Z(92)+AX(18,13)*Z(101)+AX(18,14)*Z(110)+AX(18,15)*Z(119)+A
                X(18,16)*Z(128)+AX(18,17)*Z(137)+AX(18,18)*Z(146)+AX(18,19)*Z(155)+A
                X(18,20)*S(50))
ZPRIME(147) = F1*(BY(4,1)*S(44)+SUM(BY(4,2:10)*Z(145:153))+BY(4,11)*S(45))+F2* (BX
                (18,1)*S(4)+BX(18,2)*Z(3)+BX(18,3)*Z(12)+BX(18,4)*Z(21)+BX(18,5)*Z(30)+
                BX(18,6)*Z(39)+BX(18,7)*Z(48)+BX(18,8)*Z(57)+BX(18,9)*Z(66)+BX(18,10)
                *Z(75)+BX(18,11)*Z(84)+BX(18,12)*Z(93)+BX(18,13)*Z(102)+BX(18,14)*Z(1
                11)+BX(18,15)*Z(120)+BX(18,16)*Z(129)+BX(18,17)*Z(138)+BX(18,18)*Z(14
                7)+BX(18,19)*Z(156)+BX(18,20)*S(51))-F3*(AX(18,1)*S(4)+AX (18,2)*Z(3)+
                AX(18,3)*Z(12)+AX(18,4)*Z(21)+AX(18,5)*Z(30)+AX(18,6)*Z(39)+AX(18,7)*
                Z(48)+AX(18,8)*Z(57)+AX(18,9)*Z(66)+AX(18,10)*Z(75)+AX(18,11)*Z(84)+
                AX(18,12)*Z(93)+AX(18,13)*Z(102)+AX(18,14)*Z(111)+AX(18,15)*Z(120)+A
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X(18,16)*Z(129)+AX(18,17)*Z(138)+AX(18,18)*Z(147)+AX(18,19)*Z(156)+A
X(18,20)*S(51))
ZPRIME(148) = F1*(BY(5,1)*S(44)+SUM(BY(5,2:10)*Z(145:153))+BY(5,11)*S(45))+F2* (BX
(18,1)*S(5)+BX(18,2)*Z(4)+BX(18,3)*Z(13)+BX(18,4)*Z(22)+BX(18,5)*Z(31)+
BX(18,6)*Z(40)+BX(18,7)*Z(49)+BX(18,8)*Z(58)+BX(18,9)*Z(67)+BX(18,10)
*Z(76)+BX(18,11)*Z(85)+BX(18,12)*Z(94)+BX(18,13)*Z(103)+BX(18,14)*Z(1
12)+BX(18,15)*Z(121)+BX(18,16)*Z(130)+BX(18,17)*Z(139)+BX(18,18)*Z(14
8)+BX(18,19)*Z(157)+BX(18,20)*S(52))-F3*(AX(18,1)*S(5)+AX (18,2)*Z(4)+
AX(18,3)*Z(13)+AX(18,4)*Z(22)+AX(18,5)*Z(31)+AX(18,6)*Z(40)+AX(18,7)*
Z(49)+AX(18,8)*Z(58)+AX(18,9)*Z(67)+AX(18,10)*Z(76)+AX(18,11)*Z(85)+
AX(18,12)*Z(94)+AX(18,13)*Z(103)+AX(18,14)*Z(112)+AX(18,15)*Z(121)+A
X(18,16)*Z(130)+AX(18,17)*Z(139)+AX(18,18)*Z(148)+AX(18,19)*Z(157)+A
X(18,20)*S(52))
ZPRIME(149) = F1*(BY(6,1)*S(44)+SUM(BY(6,2:10)*Z(145:153))+BY(6,11)*S(45))+F2* (BX
(18,1)*S(6)+BX(18,2)*Z(5)+BX(18,3)*Z(14)+BX(18,4)*Z(23)+BX(18,5)*Z(32)+
BX(18,6)*Z(41)+BX(18,7)*Z(50)+BX(18,8)*Z(59)+BX(18,9)*Z(68)+BX(18,10)
*Z(77)+BX(18,11)*Z(86)+BX(18,12)*Z(95)+BX(18,13)*Z(104)+BX(18,14)*Z(1
13)+BX(18,15)*Z(122)+BX(18,16)*Z(131)+BX(18,17)*Z(140)+BX(18,18)*Z(14
9)+BX(18,19)*Z(158)+BX(18,20)*S(53))-F3*(AX(18,1)*S(6)+AX (18,2)*Z(5)+
AX(18,3)*Z(14)+AX(18,4)*Z(23)+AX(18,5)*Z(32)+AX(18,6)*Z(41)+AX(18,7)*
Z(50)+AX(18,8)*Z(59)+AX(18,9)*Z(68)+AX(18,10)*Z(77)+AX(18,11)*Z(86)+
AX(18,12)*Z(95)+AX(18,13)*Z(104)+AX(18,14)*Z(113)+AX(18,15)*Z(122)+A
X(18,16)*Z(131)+AX(18,17)*Z(140)+AX(18,18)*Z(149)+AX(18,19)*Z(158)+A
X(18,20)*S(53))
ZPRIME(150) = F1*(BY(7,1)*S(44)+SUM(BY(7,2:10)*Z(145:153))+BY(7,11)*S(45))+F2* (BX
(18,1)*S(7)+BX(18,2)*Z(6)+BX(18,3)*Z(15)+BX(18,4)*Z(24)+BX(18,5)*Z(33)+
BX(18,6)*Z(42)+BX(18,7)*Z(51)+BX(18,8)*Z(60)+BX(18,9)*Z(69)+BX(18,10)
*Z(78)+BX(18,11)*Z(87)+BX(18,12)*Z(96)+BX(18,13)*Z(105)+BX(18,14)*Z(1
14)+BX(18,15)*Z(123)+BX(18,16)*Z(132)+BX(18,17)*Z(141)+BX(18,18)*Z(15
0)+BX(18,19)*Z(159)+BX(18,20)*S(54))-F3*(AX(18,1)*S(7)+AX (18,2)*Z(6)+
AX(18,3)*Z(15)+AX(18,4)*Z(24)+AX(18,5)*Z(33)+AX(18,6)*Z(42)+AX(18,7)*
Z(51)+AX(18,8)*Z(60)+AX(18,9)*Z(69)+AX(18,10)*Z(78)+AX(18,11)*Z(87)+
AX(18,12)*Z(96)+AX(18,13)*Z(105)+AX(18,14)*Z(114)+AX(18,15)*Z(123)+A
X(18,16)*Z(132)+AX(18,17)*Z(141)+AX(18,18)*Z(150)+AX(18,19)*Z(159)+A
X(18,20)*S(54))
ZPRIME(151) = F1*(BY(8,1)*S(44)+SUM(BY(8,2:10)*Z(145:153))+BY(8,11)*S(45))+F2* (BX
(18,1)*S(8)+BX(18,2)*Z(7)+BX(18,3)*Z(16)+BX(18,4)*Z(25)+BX(18,5)*Z(34)+
BX(18,6)*Z(43)+BX(18,7)*Z(52)+BX(18,8)*Z(61)+BX(18,9)*Z(70)+BX(18,10)
*Z(79)+BX(18,11)*Z(88)+BX(18,12)*Z(97)+BX(18,13)*Z(106)+BX(18,14)*Z(1
15)+BX(18,15)*Z(124)+BX(18,16)*Z(133)+BX(18,17)*Z(142)+BX(18,18)*Z(15
1)+BX(18,19)*Z(160)+BX(18,20)*S(55))-F3*(AX(18,1)*S(8)+AX (18,2)*Z(7)+
AX(18,3)*Z(16)+AX(18,4)*Z(25)+AX(18,5)*Z(34)+AX(18,6)*Z(43)+AX(18,7)*
Z(52)+AX(18,8)*Z(61)+AX(18,9)*Z(70)+AX(18,10)*Z(79)+AX(18,11)*Z(88)+
AX(18,12)*Z(97)+AX(18,13)*Z(106)+AX(18,14)*Z(115)+AX(18,15)*Z(124)+A
X(18,16)*Z(133)+AX(18,17)*Z(142)+AX(18,18)*Z(151)+AX(18,19)*Z(160)+A
X(18,20)*S(55))
ZPRIME(152) = F1*(BY(9,1)*S(44)+SUM(BY(9,2:10)*Z(145:153))+BY(9,11)*S(45))+F2* (BX
(18,1)*S(9)+BX(18,2)*Z(8)+BX(18,3)*Z(17)+BX(18,4)*Z(26)+BX(18,5)*Z(35)+
BX(18,6)*Z(44)+BX(18,7)*Z(53)+BX(18,8)*Z(62)+BX(18,9)*Z(71)+BX(18,10)
*Z(80)+BX(18,11)*Z(89)+BX(18,12)*Z(98)+BX(18,13)*Z(107)+BX(18,14)*Z(1
16)+BX(18,15)*Z(125)+BX(18,16)*Z(134)+BX(18,17)*Z(143)+BX(18,18)*Z(15
2)+BX(18,19)*Z(161)+BX(18,20)*S(56))-F3*(AX(18,1)*S(9)+AX (18,2)*Z(8)+
AX(18,3)*Z(17)+AX(18,4)*Z(26)+AX(18,5)*Z(35)+AX(18,6)*Z(44)+AX(18,7)*
Z(53)+AX(18,8)*Z(62)+AX(18,9)*Z(71)+AX(18,10)*Z(80)+AX(18,11)*Z(89)+
AX(18,12)*Z(98)+AX(18,13)*Z(107)+AX(18,14)*Z(116)+AX(18,15)*Z(125)+A

X(18,16)*Z(134)+AX(18,17)*Z(143)+AX(18,18)*Z(152)+AX(18,19)*Z(161)+A
X(18,20)*S(56))

ZPRIME(153) = F1*(BY(10,1)*S(44)+SUM(BY(10,2:10)*Z(145:153))+BY(10,11)*S(45))+F2*
(BX(18,1)*S(10)+BX(18,2)*Z(9)+BX(18,3)*Z(18)+BX(18,4)*Z(27)+BX(18,5)*Z
(36)+BX(18,6)*Z(45)+BX(18,7)*Z(54)+BX(18,8)*Z(63)+BX(18,9)*Z(72)+BX(1
8,10)*Z(81)+BX(18,11)*Z(90)+BX(18,12)*Z(99)+BX(18,13)*Z(108)+BX(18,14)
*Z(117)+BX(18,15)*Z(126)+BX(18,16)*Z(135)+BX(18,17)*Z(144)+BX(18,18)*
Z(153)+BX(18,19)*Z(162)+BX(18,20)*S(57))-F3*(AX(18,1)*S(10)+AX (18,2)*
Z(9)+AX(18,3)*Z(18)+AX(18,4)*Z(27)+AX(18,5)*Z(36)+AX(18,6)*Z(45)+AX(
18,7)*Z(54)+AX(18,8)*Z(63)+AX(18,9)*Z(72)+AX(18,10)*Z(81)+AX(18,11)*Z
(90)+AX(18,12)*Z(99)+AX(18,13)*Z(108)+AX(18,14)*Z(117)+AX(18,15)*Z(12
6)+AX(18,16)*Z(135)+AX(18,17)*Z(144)+AX(18,18)*Z(153)+AX(18,19)*Z(162
)+AX(18,20)*S(57))

ZPRIME(154) = F1*(BY(2,1)*S(46)+SUM(BY(2,2:10)*Z(154:162))+BY(2,11)*S(47))+F2* (BX
(19,1)*S(2)+BX(19,2)*Z(1)+BX(19,3)*Z(10)+BX(19,4)*Z(19)+BX(19,5)*Z(28)+
BX(19,6)*Z(37)+BX(19,7)*Z(46)+BX(19,8)*Z(55)+BX(19,9)*Z(64)+BX(19,10)
*Z(73)+BX(19,11)*Z(82)+BX(19,12)*Z(91)+BX(19,13)*Z(100)+BX(19,14)*Z(1
09)+BX(19,15)*Z(118)+BX(19,16)*Z(127)+BX(19,17)*Z(136)+BX(19,18)*Z(14
5)+BX(19,19)*Z(154)+BX(19,20)*S(49))-F3*(AX(19,1)*S(2)+AX (19,2)*Z(1)+
AX(19,3)*Z(10)+AX(19,4)*Z(19)+AX(19,5)*Z(28)+AX(19,6)*Z(37)+AX(19,7)*
Z(46)+AX(19,8)*Z(55)+AX(19,9)*Z(64)+AX(19,10)*Z(73)+AX(19,11)*Z(82)+
AX(19,12)*Z(91)+AX(19,13)*Z(100)+AX(19,14)*Z(109)+AX(19,15)*Z(118)+A
X(19,16)*Z(127)+AX(19,17)*Z(136)+AX(19,18)*Z(145)+AX(19,19)*Z(154)+A
X(19,20)*S(49))

ZPRIME(155) = F1*(BY(3,1)*S(46)+SUM(BY(3,2:10)*Z(154:162))+BY(3,11)*S(47))+F2* (BX
(19,1)*S(3)+BX(19,2)*Z(2)+BX(19,3)*Z(11)+BX(19,4)*Z(20)+BX(19,5)*Z(29)+
BX(19,6)*Z(38)+BX(19,7)*Z(47)+BX(19,8)*Z(56)+BX(19,9)*Z(65)+BX(19,10)
*Z(74)+BX(19,11)*Z(83)+BX(19,12)*Z(92)+BX(19,13)*Z(101)+BX(19,14)*Z(1
10)+BX(19,15)*Z(119)+BX(19,16)*Z(128)+BX(19,17)*Z(137)+BX(19,18)*Z(14
6)+BX(19,19)*Z(155)+BX(19,20)*S(50))-F3*(AX(19,1)*S(3)+AX (19,2)*Z(2)+
AX(19,3)*Z(11)+AX(19,4)*Z(20)+AX(19,5)*Z(29)+AX(19,6)*Z(38)+AX(19,7)*
Z(47)+AX(19,8)*Z(56)+AX(19,9)*Z(65)+AX(19,10)*Z(74)+AX(19,11)*Z(83)+
AX(19,12)*Z(92)+AX(19,13)*Z(101)+AX(19,14)*Z(110)+AX(19,15)*Z(119)+A
X(19,16)*Z(128)+AX(19,17)*Z(137)+AX(19,18)*Z(146)+AX(19,19)*Z(155)+A
X(19,20)*S(50))

ZPRIME(156) = F1*(BY(4,1)*S(46)+SUM(BY(4,2:10)*Z(154:162))+BY(4,11)*S(47))+F2* (BX
(19,1)*S(4)+BX(19,2)*Z(3)+BX(19,3)*Z(12)+BX(19,4)*Z(21)+BX(19,5)*Z(30)+
BX(19,6)*Z(39)+BX(19,7)*Z(48)+BX(19,8)*Z(57)+BX(19,9)*Z(66)+BX(19,10)
*Z(75)+BX(19,11)*Z(84)+BX(19,12)*Z(93)+BX(19,13)*Z(102)+BX(19,14)*Z(1
11)+BX(19,15)*Z(120)+BX(19,16)*Z(129)+BX(19,17)*Z(138)+BX(19,18)*Z(14
7)+BX(19,19)*Z(156)+BX(19,20)*S(51))-F3*(AX(19,1)*S(4)+AX (19,2)*Z(3)+
AX(19,3)*Z(12)+AX(19,4)*Z(21)+AX(19,5)*Z(30)+AX(19,6)*Z(39)+AX(19,7)*
Z(48)+AX(19,8)*Z(57)+AX(19,9)*Z(66)+AX(19,10)*Z(75)+AX(19,11)*Z(84)+
AX(19,12)*Z(93)+AX(19,13)*Z(102)+AX(19,14)*Z(111)+AX(19,15)*Z(120)+A
X(19,16)*Z(129)+AX(19,17)*Z(138)+AX(19,18)*Z(147)+AX(19,19)*Z(156)+A
X(19,20)*S(51))

ZPRIME(157) = F1*(BY(5,1)*S(46)+SUM(BY(5,2:10)*Z(154:162))+BY(5,11)*S(47))+F2* (BX
(19,1)*S(5)+BX(19,2)*Z(4)+BX(19,3)*Z(13)+BX(19,4)*Z(22)+BX(19,5)*Z(31)+
BX(19,6)*Z(40)+BX(19,7)*Z(49)+BX(19,8)*Z(58)+BX(19,9)*Z(67)+BX(19,10)
*Z(76)+BX(19,11)*Z(85)+BX(19,12)*Z(94)+BX(19,13)*Z(103)+BX(19,14)*Z(1
12)+BX(19,15)*Z(121)+BX(19,16)*Z(130)+BX(19,17)*Z(139)+BX(19,18)*Z(14
8)+BX(19,19)*Z(157)+BX(19,20)*S(52))-F3*(AX(19,1)*S(5)+AX (19,2)*Z(4)+
AX(19,3)*Z(13)+AX(19,4)*Z(22)+AX(19,5)*Z(31)+AX(19,6)*Z(40)+AX(19,7)*
Z(49)+AX(19,8)*Z(58)+AX(19,9)*Z(67)+AX(19,10)*Z(76)+AX(19,11)*Z(85)+
AX(19,12)*Z(94)+AX(19,13)*Z(103)+AX(19,14)*Z(112)+AX(19,15)*Z(121)+A

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              X(19,16)*Z(130)+AX(19,17)*Z(139)+AX(19,18)*Z(148)+AX(19,19)*Z(157)+A
              X(19,20)*S(52))
ZPRIME(158) = F1*(BY(6,1)*S(46)+SUM(BY(6,2:10)*Z(154:162))+BY(6,11)*S(47))+F2* (BX
              (19,1)*S(6)+BX(19,2)*Z(5)+BX(19,3)*Z(14)+BX(19,4)*Z(23)+BX(19,5)*Z(32)+
              BX(19,6)*Z(41)+BX(19,7)*Z(50)+BX(19,8)*Z(59)+BX(19,9)*Z(68)+BX(19,10)
              *Z(77)+BX(19,11)*Z(86)+BX(19,12)*Z(95)+BX(19,13)*Z(104)+BX(19,14)*Z(1
              13)+BX(19,15)*Z(122)+BX(19,16)*Z(131)+BX(19,17)*Z(140)+BX(19,18)*Z(14
              9)+BX(19,19)*Z(158)+BX(19,20)*S(53))-F3*(AX(19,1)*S(6)+AX (19,2)*Z(5)+
              AX(19,3)*Z(14)+AX(19,4)*Z(23)+AX(19,5)*Z(32)+AX(19,6)*Z(41)+AX(19,7)*
              Z(50)+AX(19,8)*Z(59)+AX(19,9)*Z(68)+AX(19,10)*Z(77)+AX(19,11)*Z(86)+
              AX(19,12)*Z(95)+AX(19,13)*Z(104)+AX(19,14)*Z(113)+AX(19,15)*Z(122)+A
              X(19,16)*Z(131)+AX(19,17)*Z(140)+AX(19,18)*Z(149)+AX(19,19)*Z(158)+A
              X(19,20)*S(53))
ZPRIME(159) = F1*(BY(7,1)*S(46)+SUM(BY(7,2:10)*Z(154:162))+BY(7,11)*S(47))+F2* (BX
              (19,1)*S(7)+BX(19,2)*Z(6)+BX(19,3)*Z(15)+BX(19,4)*Z(24)+BX(19,5)*Z(33)+
              BX(19,6)*Z(42)+BX(19,7)*Z(51)+BX(19,8)*Z(60)+BX(19,9)*Z(69)+BX(19,10)
              *Z(78)+BX(19,11)*Z(87)+BX(19,12)*Z(96)+BX(19,13)*Z(105)+BX(19,14)*Z(1
              14)+BX(19,15)*Z(123)+BX(19,16)*Z(132)+BX(19,17)*Z(141)+BX(19,18)*Z(15
              0)+BX(19,19)*Z(159)+BX(19,20)*S(54))-F3*(AX(19,1)*S(7)+AX (19,2)*Z(6)+
              AX(19,3)*Z(15)+AX(19,4)*Z(24)+AX(19,5)*Z(33)+AX(19,6)*Z(42)+AX(19,7)*
              Z(51)+AX(19,8)*Z(60)+AX(19,9)*Z(69)+AX(19,10)*Z(78)+AX(19,11)*Z(87)+
              AX(19,12)*Z(96)+AX(19,13)*Z(105)+AX(19,14)*Z(114)+AX(19,15)*Z(123)+A
              X(19,16)*Z(132)+AX(19,17)*Z(141)+AX(19,18)*Z(150)+AX(19,19)*Z(159)+A
              X(19,20)*S(54))
ZPRIME(160) = F1*(BY(8,1)*S(46)+SUM(BY(8,2:10)*Z(154:162))+BY(8,11)*S(47))+F2* (BX
              (19,1)*S(8)+BX(19,2)*Z(7)+BX(19,3)*Z(16)+BX(19,4)*Z(25)+BX(19,5)*Z(34)+
              BX(19,6)*Z(43)+BX(19,7)*Z(52)+BX(19,8)*Z(61)+BX(19,9)*Z(70)+BX(19,10)
              *Z(79)+BX(19,11)*Z(88)+BX(19,12)*Z(97)+BX(19,13)*Z(106)+BX(19,14)*Z(1
              15)+BX(19,15)*Z(124)+BX(19,16)*Z(133)+BX(19,17)*Z(142)+BX(19,18)*Z(15
              1)+BX(19,19)*Z(160)+BX(19,20)*S(55))-F3*(AX(19,1)*S(8)+AX (19,2)*Z(7)+
              AX(19,3)*Z(16)+AX(19,4)*Z(25)+AX(19,5)*Z(34)+AX(19,6)*Z(43)+AX(19,7)*
              Z(52)+AX(19,8)*Z(61)+AX(19,9)*Z(70)+AX(19,10)*Z(79)+AX(19,11)*Z(88)+
              AX(19,12)*Z(97)+AX(19,13)*Z(106)+AX(19,14)*Z(115)+AX(19,15)*Z(124)+A
              X(19,16)*Z(133)+AX(19,17)*Z(142)+AX(19,18)*Z(151)+AX(19,19)*Z(160)+A
              X(19,20)*S(55))
ZPRIME(161) = F1*(BY(9,1)*S(46)+SUM(BY(9,2:10)*Z(154:162))+BY(9,11)*S(47))+F2* (BX
              (19,1)*S(9)+BX(19,2)*Z(8)+BX(19,3)*Z(17)+BX(19,4)*Z(26)+BX(19,5)*Z(35)+
              BX(19,6)*Z(44)+BX(19,7)*Z(53)+BX(19,8)*Z(62)+BX(19,9)*Z(71)+BX(19,10)
              *Z(80)+BX(19,11)*Z(89)+BX(19,12)*Z(98)+BX(19,13)*Z(107)+BX(19,14)*Z(1
              16)+BX(19,15)*Z(125)+BX(19,16)*Z(134)+BX(19,17)*Z(143)+BX(19,18)*Z(15
              2)+BX(19,19)*Z(161)+BX(19,20)*S(56))-F3*(AX(19,1)*S(9)+AX (19,2)*Z(8)+
              AX(19,3)*Z(17)+AX(19,4)*Z(26)+AX(19,5)*Z(35)+AX(19,6)*Z(44)+AX(19,7)*
              Z(53)+AX(19,8)*Z(62)+AX(19,9)*Z(71)+AX(19,10)*Z(80)+AX(19,11)*Z(89)+
              AX(19,12)*Z(98)+AX(19,13)*Z(107)+AX(19,14)*Z(116)+AX(19,15)*Z(125)+A
              X(19,16)*Z(134)+AX(19,17)*Z(143)+AX(19,18)*Z(152)+AX(19,19)*Z(161)+A
              X(19,20)*S(56))
ZPRIME(162) = F1*(BY(10,1)*S(46)+SUM(BY(10,2:10)*Z(154:162))+BY(10,11)*S(47))+F2*
              (BX(19,1)*S(10)+BX(19,2)*Z(9)+BX(19,3)*Z(18)+BX(19,4)*Z(27)+BX(19,5)*Z
              (36)+BX(19,6)*Z(45)+BX(19,7)*Z(54)+BX(19,8)*Z(63)+BX(19,9)*Z(72)+BX(1
              9,10)*Z(81)+BX(19,11)*Z(90)+BX(19,12)*Z(99)+BX(19,13)*Z(108)+BX(19,14)
              *Z(117)+BX(19,15)*Z(126)+BX(19,16)*Z(135)+BX(19,17)*Z(144)+BX(19,18)*
              Z(153)+BX(19,19)*Z(162)+BX(19,20)*S(57))-F3*(AX(19,1)*S(10)+AX (19,2)*
              Z(9)+AX(19,3)*Z(18)+AX(19,4)*Z(27)+AX(19,5)*Z(36)+AX(19,6)*Z(45)+AX(
              19,7)*Z(54)+AX(19,8)*Z(63)+AX(19,9)*Z(72)+AX(19,10)*Z(81)+AX(19,11)*Z
              (90)+AX(19,12)*Z(99)+AX(19,13)*Z(108)+AX(19,14)*Z(117)+AX(19,15)*Z(12
```

```
              6)+AX(19,16)*Z(135)+AX(19,17)*Z(144)+AX(19,18)*Z(153)+AX(19,19)*Z(162
              )+AX(19,20)*S(57))
        RETURN
        END
```

!C SUBROUTINE TO CALCULATE THE TEMPERATURES AT THE REQUIRED RADIAL AND AXIAL LOCATIONS.

```
        SUBROUTINE TEMPAVG(NEQ, TEMAVG, T2)
        DOUBLE PRECISION :: T2(NEQ), TEMAVG(12)
        TEMAVG(1)= 1./2.*T2(52)+1./2.*T2(43)
        TEMAVG(2)= 1./2.*T2(50)+1./2.*T2(41)
        TEMAVG(3)= 1./2.*T2(48)+1./2.*T2(39)
        TEMAVG(4)= 3./13.*T2(70)+10./13.*T2(61)
        TEMAVG(5)= 3./13.*T2(68)+10./13.*T2(59)
        TEMAVG(6)= 3./13.*T2(66)+10./13.*T2(57)
        TEMAVG(7)= 9./13.*T2(97)+4./13.*T2(88)
        TEMAVG(8)= 9./13.*T2(95)+4./13.*T2(86)
        TEMAVG(9)= 9./13.*T2(93)+4./13.*T2(84)
        TEMAVG(10)= 4./10.*T2(124)+6./10.*T2(115)
        TEMAVG(11)= 4./10.*T2(122)+6./10.*T2(113)
        TEMAVG(12)= 4./10.*T2(120)+6./10.*T2(111)
        RETURN
        END
```

!C SUBROUTINE TO READ THE SHIFTED LEGENDRE MATRIX PARAMETERS AX, BX, AY AND BY. IT ALSO READS THE ROOTS OF THE SHIFTED LEGENDRE POLYNOMIALS.

```
        SUBROUTINE LEGANDMATRIX (AY, BY, AX, BX, DY, DX)
        DOUBLE PRECISION :: AX(20,20), BX(20,20), AY(11,11), BY(11,11), DY(11), DX(20)
        OPEN(6,FILE='LEGANDMATRIX.IN',STATUS='UNKNOWN')
        DO I=1,11
        DO J=1,11
        READ(6,*) AY(I,J)
        ENDDO
        ENDDO
        DO I=1,11
        DO J=1,11
        READ(6,*) BY(I,J)
        ENDDO
        ENDDO
        DO I=1,20
        DO J=1,20
        READ(6,*) AX(I,J)
        ENDDO
        ENDDO
        DO I=1,20
        DO J=1,20
        READ(6,*) BX(I,J)
        ENDDO
        ENDDO
        DO J=1,11
        READ(6,*) DY(J)
        ENDDO
        DO I=1,20
        READ(6,*) DX(I)
```

```
      ENDDO
      RETURN
      END

!C    SUBROUTINE TO CALCULATE THE AXIAL AND RADIAL DISPERSION.
      SUBROUTINE AXIALDISPER (RADIAL, AXIAL, DZDX, DZDY, NEQ, Z, S, NB, F1, F2, AX,
      AY, BX,BY)
      DOUBLE PRECISION :: AX(20,20), BX(20,20), AY(11,11), BY(11,11)
      DOUBLE PRECISION :: Z(NEQ), S(NB), RADIAL(8), AXIAL(8), DZDY(8), DZDX(8), F1, F2

!C    AT NODE 39, X=25 cm AND Y = 2 cm.

      RADIAL(1) = F1*(BY(4,1)*S(20)+SUM(BY(4,2:10)*Z(37:45))+BY(4,11)*S(21))
      AXIAL (1) = F2*(BX(6,1)*S(4)+BX(6,2)*Z(3)+BX(6,3)*Z(12)+BX(6,4)*Z(21)+BX (6,5)* Z(30)
                  +BX(6,6)*Z(39)+BX(6,7)*Z(48)+BX(6,8)*Z(57)+BX(6,9)*Z(66)+BX(6,10) *Z(75)
                  +BX(6,11)*Z(84)+BX(6,12)*Z(93)+BX(6,13)*Z(102)+BX(6,14)*Z(111)+BX(6,15)
                  *Z(120)+BX(6,16)*Z(129)+BX(6,17)*Z(138)+BX(6,18)*Z(147)+BX(6,19)*Z(156)
                  +BX(6,20)*S(51))
      DZDX  (1) = AX(6,1)*S(4)+AX(6,2)*Z(3)+AX(6,3)*Z(12)+AX(6,4)*Z(21)+AX(6,5)*Z(30) +
                  AX(6,6)*Z(39) +AX(6,7)*Z(48)+AX(6,8)*Z(57)+AX(6,9)*Z(66)+AX(6,10)*Z(75)
                  +AX(6,11)*Z(84)+AX(6,12)*Z(93)+AX(6,13)*Z(102)+AX(6,14)* Z(111)+ AX
                  (6,15) *Z(120)+AX(6,16)*Z(129)+AX(6,17)*Z(138)+AX(6,18)*Z(147)+AX(6,19)*
                  Z(156)+AX(6,20)*S(51)
       DZDY  (1) = AY(4,1)*S(20)+SUM(AY(4,2:10)*Z(37:45))+AY(4,11)*S(21)

!C    AT NODE 43, X=25 cm AND Y = 8 cm.

      RADIAL(2) = F1*(BY(8,1)*S(20)+SUM(BY(8,2:10)*Z(37:45))+BY(8,11)*S(21))
      AXIAL (2) = F2*(BX(6,1)*S(8)+BX(6,2)*Z(7)+BX(6,3)*Z(16)+BX(6,4)*Z(25)+BX(6,5)* Z(34)
                  +BX(6,6)*Z(43)+BX(6,7)*Z(52)+BX(6,8)*Z(61)+BX(6,9)*Z(70)+BX(6,10)*Z(79)
                  + BX(6,11)*Z(88)+BX(6,12)*Z(97)+BX(6,13)*Z(106)+BX(6,14)*Z(115)+ BX
                  (6,15)*Z(124)+BX(6,16)*Z(133)+BX(6,17)*Z(142)+BX(6,18)*Z(151) +BX (6,19)
                  *Z(160)+BX(6,20)*S(55))
      DZDX  (2) = AX(6,1)*S(8)+AX(6,2)*Z(7)+AX(6,3)*Z(16)+AX(6,4)*Z(25)+AX(6,5)* Z(34)+
                  AX(6,6)*Z(43)+AX(6,7)*Z(52)+AX(6,8)*Z(61)+AX(6,9)*Z(70)+AX(6,10)*Z(79)+
                  AX(6,11)*Z(88)+AX(6,12)*Z(97)+AX(6,13)*Z(106)+AX(6,14)*Z(115)+AX(6,15)
                  *Z(124)+AX(6,16)*Z(133)+AX(6,17)*Z(142)+AX(6,18)*Z(151)+AX(6,19)*Z(160
                  )+AX(6,20)*S(55)
      DZDY  (2) = AY(8,1)*S(20)+SUM(AY(8,2:10)*Z(37:45))+AY(8,11)*S(21)

!C    AT NODE 66, X=60 cm AND Y = 2 cm.

      RADIAL(3) = F1*(BY(4,1)*S(26)+SUM(BY(4,2:10)*Z(64:72))+BY(4,11)*S(27))
      AXIAL (3) = F2*(BX(9,1)*S(4)+BX(9,2)*Z(3)+BX(9,3)*Z(12)+BX(9,4)*Z(21)+BX(9,5)*Z(30)
                  +BX(9,6)*Z(39)+BX(9,7)*Z(48)+BX(9,8)*Z(57)+BX(9,9)*Z(66)+BX(9,10)*Z(75)
                  +BX(9,11)*Z(84)+BX(9,12)*Z(93)+BX(9,13)*Z(102)+BX(9,14)*Z(111)+BX(9,15)
                  *Z(120)+BX(9,16)*Z(129)+BX(9,17)*Z(138)+BX(9,18)*Z(147)+BX(9,19)*Z(156)
                  +BX(9,20)*S(51))
      DZDX  (3) = AX(9,1)*S(4)+AX(9,2)*Z(3)+AX(9,3)*Z(12)+AX(9,4)*Z(21)+AX(9,5)*Z(30) +AX
                  (9,6)*Z(39)+AX(9,7)*Z(48)+AX(9,8)*Z(57)+AX(9,9)*Z(66)+AX(9,10)*Z(75)+AX
                  (9,11)*Z(84)+AX(9,12)*Z(93)+AX(9,13)*Z(102)+AX(9,14)*Z(111)+AX(9,15)*Z(
                  120)+AX(9,16)*Z(129)+AX(9,17)*Z(138)+AX(9,18)*Z(147)+AX(9,19)*Z(156)+A
                  X(9,20)*S(51)
      DZDY  (3) = AY(4,1)*S(26)+SUM(AY(4,2:10)*Z(64:72))+AY(4,11)*S(27)
```

!C *AT NODE 70, X=60 cm AND Y = 8 cm.*

```
RADIAL(4) = F1*(BY(8,1)*S(26)+SUM(BY(8,2:10)*Z(64:72))+BY(8,11)*S(27))
AXIAL (4) = F2*(BX(9,1)*S(8)+BX(9,2)*Z(7)+BX(9,3)*Z(16)+BX(9,4)*Z(25)+BX(9,5)*Z(34)
            +BX(9,6)*Z(43)+BX(9,7)*Z(52)+BX(9,8)*Z(61)+BX(9,9)*Z(70)+BX(9,10)*Z(79)
            +BX(9,11)*Z(88)+BX(9,12)*Z(97)+BX(9,13)*Z(106)+BX(9,14)*Z(115)+BX(9,15)
            *Z(124)+BX(9,16)*Z(133)+BX(9,17)*Z(142)+BX(9,18)*Z(151)+BX(9,19)*Z(160)
            +BX(9,20)*S(55))
DZDX (4) = AX(9,1)*S(8)+AX(9,2)*Z(7)+AX(9,3)*Z(16)+AX(9,4)*Z(25)+AX(9,5)*Z(34) +AX
            (9,6)*Z(43)+AX(9,7)*Z(52)+AX(9,8)*Z(61)+AX(9,9)*Z(70)+AX(9,10)*Z(79)+AX
            (9,11)*Z(88)+AX(9,12)*Z(97)+AX(9,13)*Z(106)+AX(9,14)*Z(115)+AX(9,15)*Z(
            124)+AX(9,16)*Z(133)+AX(9,17)*Z(142)+AX(9,18)*Z(151)+AX(9,19)*Z(160)+A
            X(9,20)*S(55)
DZDY (4) = AY(8,1)*S(26)+SUM(AY(8,2:10)*Z(64:72))+AY(8,11)*S(27)
```

!C *AT NODE 93, X=100 cm AND Y = 2 cm.*

```
RADIAL(5) = F1*(BY(4,1)*S(32)+SUM(BY(4,2:10)*Z(91:99))+BY(4,11)*S(33))
AXIAL (5) = F2*(BX(12,1)*S(4)+BX(12,2)*Z(3)+BX(12,3)*Z(12)+BX(12,4)*Z(21)+BX(12,5)
            *Z(30)+BX(12,6)*Z(39)+BX(12,7)*Z(48)+BX(12,8)*Z(57)+BX(12,9)*Z(66)+BX(
            12,10)*Z(75)+BX(12,11)*Z(84)+BX(12,12)*Z(93)+BX(12,13)*Z(102)+BX(12,14)
            *Z(111)+BX(12,15)*Z(120)+BX(12,16)*Z(129)+BX(12,17)*Z(138)+BX(12,18)*Z
            (147)+BX(12,19)*Z(156)+BX(12,20)*S(51))
DZDX (5) = AX(12,1)*S(4)+AX(12,2)*Z(3)+AX(12,3)*Z(12)+AX(12,4)*Z(21)+AX(12,5)*
            Z(30)+AX(12,6)*Z(39)+AX(12,7)*Z(48)+AX(12,8)*Z(57)+AX(12,9)*Z(66)+AX(1
            2,10)*Z(75)+AX(12,11)*Z(84)+AX(12,12)*Z(93)+AX(12,13)*Z(102)+AX(12,14)*
            Z(111)+AX(12,15)*Z(120)+AX(12,16)*Z(129)+AX(12,17)*Z(138)+AX(12,18)*Z(
            147)+AX(12,19)*Z(156)+AX(12,20)*S(51)
DZDY (5) = AY(4,1)*S(32)+SUM(AY(4,2:10)*Z(91:99))+AY(4,11)*S(33)
```

!C *AT NODE 97, X=100 cm AND Y = 8 cm.*

```
RADIAL(6) = F1*(BY(8,1)*S(32)+SUM(BY(8,2:10)*Z(91:99))+BY(8,11)*S(33))
AXIAL (6) = F2*(BX(12,1)*S(8)+BX(12,2)*Z(7)+BX(12,3)*Z(16)+BX(12,4)*Z(25)+BX(12,5)
            *Z(34)+BX(12,6)*Z(43)+BX(12,7)*Z(52)+BX(12,8)*Z(61)+BX(12,9)*Z(70)+BX(
            12,10)*Z(79)+BX(12,11)*Z(88)+BX(12,12)*Z(97)+BX(12,13)*Z(106)+BX(12,14)
            *Z(115)+BX(12,15)*Z(124)+BX(12,16)*Z(133)+BX(12,17)*Z(142)+BX(12,18)*Z
            (151)+BX(12,19)*Z(160)+BX(12,20)*S(55))
DZDX (6) = AX(12,1)*S(8)+AX(12,2)*Z(7)+AX(12,3)*Z(16)+AX(12,4)*Z(25)+AX(12,5) *
            Z(34)+AX(12,6)*Z(43)+AX(12,7)*Z(52)+AX(12,8)*Z(61)+AX(12,9)*Z(70)+AX(1
            2,10)*Z(79)+AX(12,11)*Z(88)+AX(12,12)*Z(97)+AX(12,13)*Z(106)+AX(12,14)*
            Z(115)+AX(12,15)*Z(124)+AX(12,16)*Z(133)+AX(12,17)*Z(142)+AX(12,18)*Z(
            151)+AX(12,19)*Z(160)+AX(12,20)*S(55)
DZDY (6) = AY(8,1)*S(32)+SUM(AY(8,2:10)*Z(91:99))+AY(8,11)*S(33)
```

!C *AT NODE 138, X=151 cm AND Y = 2 cm.*

```
RADIAL(7) = F1*(BY(4,1)*S(42)+SUM(BY(4,2:10)*Z(136:144))+BY(4,11)*S(43))
AXIAL (7) = F2*(BX(17,1)*S(4)+BX(17,2)*Z(3)+BX(17,3)*Z(12)+BX(17,4)*Z(21)+BX(17,5)
            *Z(30)+BX(17,6)*Z(39)+BX(17,7)*Z(48)+BX(17,8)*Z(57)+BX(17,9)*Z(66)+BX(
            17,10)*Z(75)+BX(17,11)*Z(84)+BX(17,12)*Z(93)+BX(17,13)*Z(102)+BX(17,14)
            *Z(111)+BX(17,15)*Z(120)+BX(17,16)*Z(129)+BX(17,17)*Z(138)+BX(17,18)*Z
            (147)+BX(17,19)*Z(156)+BX(17,20)*S(51))
DZDX (7) = AX(17,1)*S(4)+AX(17,2)*Z(3)+AX(17,3)*Z(12)+AX(16,4)*Z(21)+AX(17,5) *
            Z(30)+AX(17,6)*Z(39)+AX(17,7)*Z(48)+AX(17,8)*Z(57)+AX(17,9)*Z(66)+AX(1
```

```
      7,10)*Z(75)+AX(17,11)*Z(84)+AX(17,12)*Z(93)+AX(17,13)*Z(102)+AX(17,14)*
      Z(111)+AX(17,15)*Z(120)+AX(17,16)*Z(129)+AX(17,17)*Z(138)+AX(17,18)*Z(
      147)+AX(17,19)*Z(156)+AX(17,20)*S(51)
DZDY (7) = AY(4,1)*S(42)+SUM(AY(4,2:10)*Z(136:144))+AY(4,11)*S(43)

!C    AT NODE 142, X=152 cm AND Y = 8 cm.

RADIAL(8) = F1*(BY(8,1)*S(42)+SUM(BY(8,2:10)*Z(136:144))+BY(8,11)*S(43))
AXIAL (8) = F2*(BX(17,1)*S(8)+BX(17,2)*Z(7)+BX(17,3)*Z(16)+BX(17,4)*Z(25)+BX(17,5)
      *Z(34)+BX(17,6)*Z(43)+BX(17,7)*Z(52)+BX(17,8)*Z(61)+BX(17,9)*Z(70)+BX(
      17,10)*Z(79)+BX(17,11)*Z(88)+BX(17,12)*Z(97)+BX(17,13)*Z(106)+BX(17,14)
      *Z(115)+BX(17,15)*Z(124)+BX(17,16)*Z(133)+BX(17,17)*Z(142)+BX(17,18)*Z
      (151)+BX(17,19)*Z(160)+BX(17,20)*S(55))
DZDX (8) = AX(17,1)*S(8)+AX(17,2)*Z(7)+AX(17,3)*Z(16)+AX(16,4)*Z(25)+AX(17,5) *
      Z(34)+AX(17,6)*Z(43)+AX(17,7)*Z(52)+AX(17,8)*Z(61)+AX(17,9)*Z(70)+AX(1
      7,10)*Z(79)+AX(17,11)*Z(88)+AX(17,12)*Z(97)+AX(17,13)*Z(106)+AX(17,14)*
      Z(115)+AX(17,15)*Z(124)+AX(17,16)*Z(133)+AX(17,17)*Z(142)+AX(17,18)*Z(
      151)+AX(17,19)*Z(160)+AX(17,20)*S(55)
DZDY (8) = AY(8,1)*S(42)+SUM(AY(8,2:10)*Z(136:144))+AY(8,11)*S(43)
RETURN
END
```

Table B1.1: Shifted Legendre Matrix for First Derivative in the y-Direction.

AY(1, 1)= -.9100000E+02	AY(5, 1)= .3542337E+01
AY(1, 2)= .1011665E+03	AY(5, 2)= -.5987251E+01
AY(1, 3)= -.1336225E+02	AY(5, 3)= .5123933E+01
AY(1, 4)= .4728605E+01	AY(5, 4)= -.7568252E+01
AY(1, 5)= -.2472876E+01	AY(5, 5)= .7247022E+00
AY(1, 6)= .1625397E+01	AY(5, 6)= .5999549E+01
AY(1, 7)= -.1261872E+01	AY(5, 7)= -.3084008E+01
AY(1, 8)= .1133164E+01	AY(5, 8)= .2333682E+01
AY(1, 9)= -.1193331E+01	AY(5, 9)= -.2260062E+01
AY(1,10)= .1636614E+01	AY(5,10)= .2982970E+01
AY(1,11)= -.1000000E+01	AY(5,11)= -.1807601E+01
AY(2, 1)= -.3900169E+02	AY(6, 1)= -.2460938E+01
AY(2, 2)= .3089918E+02	AY(6, 2)= .4093833E+01
AY(2, 3)= .1029593E+02	AY(6, 3)= -.3224699E+01
AY(2, 4)= -.3199487E+01	AY(6, 4)= .3667533E+01
AY(2, 5)= .1611337E+01	AY(6, 5)= -.6341212E+01
AY(2, 6)= -.1042402E+01	AY(6, 6)= .4819557E-14
AY(2, 7)= .8028011E+00	AY(6, 7)= .6341212E+01
AY(2, 8)= -.7177486E+00	AY(6, 8)= -.3667533E+01
AY(2, 9)= .7540180E+00	AY(6, 9)= .3224699E+01
AY(2,10)= -.1032887E+01	AY(6,10)= -.4093833E+01
AY(2,11)= .6309469E+00	AY(6,11)= .2460938E+01
AY(3, 1)= .1113416E+02	AY(7, 1)= .1807601E+01
AY(3, 2)= -.2225344E+02	AY(7, 2)= -.2982970E+01
AY(3, 3)= .5554065E+01	AY(7, 3)= .2260062E+01
AY(3, 4)= .7495047E+01	AY(7, 4)= -.2333682E+01
AY(3, 5)= -.2980533E+01	AY(7, 5)= .3084008E+01
AY(3, 6)= .1774704E+01	AY(7, 6)= -.5999549E+01
AY(3, 7)= -.1314652E+01	AY(7, 7)= -.7247022E+00
AY(3, 8)= .1151402E+01	AY(7, 8)= .7568252E+01
AY(3, 9)= -.1196128E+01	AY(7, 9)= -.5123933E+01
AY(3,10)= .1629720E+01	AY(7,10)= .5987251E+01
AY(3,11)= -.9943492E+00	AY(7,11)= -.3542337E+01
AY(4, 1)= -.5658992E+01	AY(8, 1)= -.1356122E+01
AY(4, 2)= .9932072E+01	AY(8, 2)= .2228086E+01
AY(4, 3)= -.1076471E+02	AY(8, 3)= -.1653694E+01
AY(4, 4)= .1966642E+01	AY(8, 4)= .1630334E+01
AY(4, 5)= .6322868E+01	AY(8, 5)= -.1949666E+01
AY(4, 6)= -.2898938E+01	AY(8, 6)= .2898938E+01
AY(4, 7)= .1949666E+01	AY(8, 7)= -.6322868E+01
AY(4, 8)= -.1630334E+01	AY(8, 8)= -.1966642E+01
AY(4, 9)= .1653694E+01	AY(8, 9)= .1076471E+02
AY(4,10)= -.2228086E+01	AY(8,10)= -.9932072E+01
AY(4,11)= .1356122E+01	AY(8,11)= .5658992E+01

Table B1.1: (Continued)

AY(9, 1)= .9943492E+00	AY(11, 1)= .1000000E+01
AY(9, 2)= -.1629720E+01	AY(11, 2)= -.1636614E+01
AY(9, 3)= .1196128E+01	AY(11, 3)= .1193331E+01
AY(9, 4)= -.1151402E+01	AY(11, 4)= -.1133164E+01
AY(9, 5)= .1314652E+01	AY(11, 5)= .1261872E+01
AY(9, 6)= -.1774704E+01	AY(11, 6)= -.1625397E+01
AY(9, 7)= .2980533E+01	AY(11, 7)= .2472876E+01
AY(9, 8)= -.7495047E+01	AY(11, 8)= -.4728605E+01
AY(9, 9)= -.5554065E+01	AY(11, 9)= .1336225E+02
AY(9,10)= .2225344E+02	AY(11,10)= -.1011665E+03
AY(9,11)= -.1113416E+02	AY(11,11)= .9100000E+02
AY(10, 1)= -.6309469E+00	
AY(10, 2)= .1032887E+01	
AY(10, 3)= -.7540180E+00	
AY(10, 4)= .7177486E+00	
AY(10, 5)= -.8028011E+00	
AY(10, 6)= .1042402E+01	
AY(10, 7)= -.1611337E+01	
AY(10, 8)= .3199487E+01	
AY(10, 9)= -.1029593E+02	
AY(10,10)= -.3089918E+02	
AY(10,11)= .3900169E+02	

Table B1.2: Shifted Legendre Matrix for Second Derivative in the y-Direction.

BY(1, 1)= .4140000E+04	BY(5, 1)= -.1583416E+02
BY(1, 2)= -.5702851E+04	BY(5, 2)= .2851533E+02
BY(1, 3)= .2105959E+04	BY(5, 3)= -.3262146E+02
BY(1, 4)= -.8116847E+03	BY(5, 4)= .9373868E+02
BY(1, 5)= .4354256E+03	BY(5, 5)= -.1407595E+03
BY(1, 6)= -.2893206E+03	BY(5, 6)= .8270639E+02
BY(1, 7)= .2258490E+03	BY(5, 7)= -.2349218E+02
BY(1, 8)= -.2034263E+03	BY(5, 8)= .1333816E+02
BY(1, 9)= .2145865E+03	BY(5, 9)= -.1106715E+02
BY(1,10)= -.2945376E+03	BY(5,10)= .1355578E+02
BY(1,11)= .1800000E+03	BY(5,11)= -.8079932E+01
BY(2, 1)= .2489506E+04	BY(6, 1)= .9843750E+01
BY(2, 2)= -.3273042E+04	BY(6, 2)= -.1691386E+02
BY(2, 3)= .9479649E+03	BY(6, 3)= .1542861E+02
BY(2, 4)= -.2337951E+03	BY(6, 4)= -.2391721E+02
BY(2, 5)= .1095878E+03	BY(6, 5)= .7822538E+02
BY(2, 6)= -.6872550E+02	BY(6, 6)= -.1253333E+03
BY(2, 7)= .5209645E+02	BY(6, 7)= .7822538E+02
BY(2, 8)= -.4617101E+02	BY(6, 8)= -.2391721E+02
BY(2, 9)= .4826878E+02	BY(6, 9)= .1542861E+02
BY(2,10)= -.6596443E+02	BY(6,10)= -.1691386E+02
BY(2,11)= .4027380E+02	BY(6,11)= .9843750E+01
BY(3, 1)= -.1479367E+03	BY(7, 1)= -.8079932E+01
BY(3, 2)= .4264935E+03	BY(7, 2)= .1355578E+02
BY(3, 3)= -.4574481E+03	BY(7, 3)= -.1106715E+02
BY(3, 4)= .2179017E+03	BY(7, 4)= .1333816E+02
BY(3, 5)= -.5640367E+02	BY(7, 5)= -.2349218E+02
BY(3, 6)= .2820473E+02	BY(7, 6)= .8270639E+02
BY(3, 7)= -.1913549E+02	BY(7, 7)= -.1407595E+03
BY(3, 8)= .1596751E+02	BY(7, 8)= .9373868E+02
BY(3, 9)= -.1614818E+02	BY(7, 9)= -.3262146E+02
BY(3,10)= .2171633E+02	BY(7,10)= .2851533E+02
BY(3,11)= -.1321166E+02	BY(7,11)= -.1583416E+02
BY(4, 1)= .3628865E+02	BY(8, 1)= .8696217E+01
BY(4, 2)= -.7291163E+02	BY(8, 2)= -.1439895E+02
BY(4, 3)= .1510435E+03	BY(8, 3)= .1106824E+02
BY(4, 4)= -.2060839E+03	BY(8, 4)= -.1172854E+02
BY(4, 5)= .1123477E+03	BY(8, 5)= .1598605E+02
BY(4, 6)= -.3030729E+02	BY(8, 6)= -.3030729E+02
BY(4, 7)= .1598605E+02	BY(8, 7)= .1123477E+03
BY(4, 8)= -.1172854E+02	BY(8, 8)= -.2060839E+03
BY(4, 9)= .1106824E+02	BY(8, 9)= .1510435E+03
BY(4,10)= -.1439895E+02	BY(8,10)= -.7291163E+02
BY(4,11)= .8696217E+01	BY(8,11)= .3628865E+02

Table B1.2: (Continued)

BY(9, 1)= -.1321166E+02	BY(11, 1)= .1800000E+03
BY(9, 2)= .2171633E+02	BY(11, 2)= -.2945376E+03
BY(9, 3)= -.1614818E+02	BY(11, 3)= .2145865E+03
BY(9, 4)= .1596751E+02	BY(11, 4)= -.2034263E+03
BY(9, 5)= -.1913549E+02	BY(11, 5)= .2258490E+03
BY(9, 6)= .2820473E+02	BY(11, 6)= -.2893206E+03
BY(9, 7)= -.5640367E+02	BY(11, 7)= .4354256E+03
BY(9, 8)= .2179017E+03	BY(11, 8)= -.8116847E+03
BY(9, 9)= -.4574481E+03	BY(11, 9)= .2105959E+04
BY(9,10)= .4264935E+03	BY(11,10)= -.5702851E+04
BY(9,11)= -.1479367E+03	BY(11,11)= .4140000E+04
BY(10, 1)= .4027380E+02	
BY(10, 2)= -.6596443E+02	
BY(10, 3)= .4826878E+02	
BY(10, 4)= -.4617101E+02	
BY(10, 5)= .5209645E+02	
BY(10, 6)= -.6872550E+02	
BY(10, 7)= .1095878E+03	
BY(10, 8)= -.2337951E+03	
BY(10, 9)= .9479649E+03	
BY(10,10)= -.3273042E+04	
BY(10,11)= .2489506E+04	

Table B2.1: Shifted Legendre Matrix for First Derivative in the x-Direction.

AX(1, 1)= -.3430000E+03	AX(3, 1)= .4220313E+02
AX(1, 2)= .3803828E+03	AX(3, 2)= -.8368152E+02
AX(1, 3)= -.4856703E+02	AX(3, 3)= .2212541E+02
AX(1, 4)= .1614893E+02	AX(3, 4)= .2557260E+02
AX(1, 5)= -.7693683E+01	AX(3, 5)= -.9254688E+01
AX(1, 6)= .4446960E+01	AX(3, 6)= .4838686E+01
AX(1, 7)= -.2907738E+01	AX(3, 7)= -.3012883E+01
AX(1, 8)= .2075143E+01	AX(3, 8)= .2091479E+01
AX(1, 9)= -.1583430E+01	AX(3, 9)= -.1568678E+01
AX(1,10)= .1275586E+01	AX(3,10)= .1249386E+01
AX(1,11)= -.1076212E+01	AX(3,11)= -.1045817E+01
AX(1,12)= .9462406E+00	AX(3,12)= .9143349E+00
AX(1,13)= -.8646710E+00	AX(3,13)= -.8320691E+00
AX(1,14)= .8206790E+00	AX(3,14)= .7873224E+00
AX(1,15)= -.8104663E+00	AX(3,15)= -.7757615E+00
AX(1,16)= .8372943E+00	AX(3,16)= .8001083E+00
AX(1,17)= -.9163862E+00	AX(3,17)= -.8746561E+00
AX(1,18)= .1096980E+01	AX(3,18)= .1046218E+01
AX(1,19)= -.1611027E+01	AX(3,19)= -.1535841E+01
AX(1,20)= .1000000E+01	AX(3,20)= .9532390E+00
AX(2, 1)= -.1478040E+03	AX(4, 1)= -.2147473E+02
AX(2, 2)= .1180539E+03	AX(4, 2)= .3738676E+02
AX(2, 3)= .3741896E+02	AX(4, 3)= -.3913414E+02
AX(2, 4)= -.1092444E+02	AX(4, 4)= .8782828E+01
AX(2, 5)= .5011197E+01	AX(4, 5)= .1959053E+02
AX(2, 6)= -.2849987E+01	AX(4, 6)= -.7869258E+01
AX(2, 7)= .1847948E+01	AX(4, 7)= .4435081E+01
AX(2, 8)= -.1312360E+01	AX(4, 8)= -.2927455E+01
AX(2, 9)= .9982880E+00	AX(4, 9)= .2132027E+01
AX(2,10)= -.8025338E+00	AX(4,10)= -.1666521E+01
AX(2,11)= .6761150E+00	AX(4,11)= .1377423E+01
AX(2,12)= -.5938412E+00	AX(4,12)= -.1193568E+01
AX(2,13)= .5422332E+00	AX(4,13)= .1079209E+01
AX(2,14)= -.5143526E+00	AX(4,14)= -.1016361E+01
AX(2,15)= .5077366E+00	AX(4,15)= .9979585E+00
AX(2,16)= -.5243805E+00	AX(4,16)= -.1026671E+01
AX(2,17)= .5737875E+00	AX(4,17)= .1120320E+01
AX(2,18)= -.6867653E+00	AX(4,18)= -.1338500E+01
AX(2,19)= .1008507E+01	AX(4,19)= .1963676E+01
AX(2,20)= -.6259911E+00	AX(4,20)= -.1218604E+01

Table B2.1: (Continued)

AX(5, 1)= .1349295E+02	AX(7, 1)= .7098181E+01
AX(5, 2)= -.2261772E+02	AX(7, 2)= -.1160957E+02
AX(5, 3)= .1867804E+02	AX(7, 3)= .8463907E+01
AX(5, 4)= -.2583656E+02	AX(7, 4)= -.8141590E+01
AX(5, 5)= .4539958E+01	AX(7, 5)= .9673128E+01
AX(5, 6)= .1620891E+02	AX(7, 6)= -.1623875E+02
AX(5, 7)= -.6949410E+01	AX(7, 7)= .1630424E+01
AX(5, 8)= .4124397E+01	AX(7, 8)= .1288503E+02
AX(5, 9)= -.2842866E+01	AX(7, 9)= -.6011382E+01
AX(5,10)= .2150489E+01	AX(7,10)= .3840109E+01
AX(5,11)= -.1740108E+01	AX(7,11)= -.2829955E+01
AX(5,12)= .1486131E+01	AX(7,12)= .2280288E+01
AX(5,13)= -.1330014E+01	AX(7,13)= -.1963144E+01
AX(5,14)= .1243292E+01	AX(7,14)= .1786445E+01
AX(5,15)= -.1214189E+01	AX(7,15)= -.1711727E+01
AX(5,16)= .1244238E+01	AX(7,16)= .1730582E+01
AX(5,17)= -.1354003E+01	AX(7,17)= -.1865759E+01
AX(5,18)= .1614799E+01	AX(7,18)= .2211776E+01
AX(5,19)= -.2366758E+01	AX(7,19)= -.3231375E+01
AX(5,20)= .1468422E+01	AX(7,20)= .2003388E+01
AX(6, 1)= -.9462660E+01	AX(8, 1)= -.5570445E+01
AX(6, 2)= .1560729E+02	AX(8, 2)= .9066290E+01
AX(6, 3)= -.1184880E+02	AX(8, 3)= -.6460891E+01
AX(6, 4)= .1259214E+02	AX(8, 4)= .5909464E+01
AX(6, 5)= -.1966668E+02	AX(8, 5)= -.6312912E+01
AX(6, 6)= .2652332E+01	AX(8, 6)= .8024489E+01
AX(6, 7)= .1415504E+02	AX(8, 7)= -.1416888E+02
AX(6, 8)= -.6361001E+01	AX(8, 8)= .9916207E+00
AX(6, 9)= .3929031E+01	AX(8, 9)= .1214043E+02
AX(6,10)= -.2805994E+01	AX(8,10)= -.5849818E+01
AX(6,11)= .2193271E+01	AX(8,11)= .3852266E+01
AX(6,12)= -.1831327E+01	AX(8,12)= -.2924533E+01
AX(6,13)= .1613749E+01	AX(8,13)= .2428651E+01
AX(6,14)= -.1492083E+01	AX(8,14)= -.2158751E+01
AX(6,15)= .1445741E+01	AX(8,15)= .2035766E+01
AX(6,16)= -.1473206E+01	AX(8,16)= -.2035754E+01
AX(6,17)= .1596903E+01	AX(8,17)= .2178530E+01
AX(6,18)= -.1899657E+01	AX(8,18)= -.2570385E+01
AX(6,19)= .2780502E+01	AX(8,19)= .3745956E+01
AX(6,20)= -.1724587E+01	AX(8,20)= -.2321094E+01

Table B2.1: (Continued)

AX(9, 1)= .4513629E+01	AX(11, 1)= .3158514E+01
AX(9, 2)= -.7323482E+01	AX(11, 2)= -.5106700E+01
AX(9, 3)= .5145857E+01	AX(11, 3)= .3532137E+01
AX(9, 4)= -.4570206E+01	AX(11, 4)= -.3039962E+01
AX(9, 5)= .4620732E+01	AX(11, 5)= .2911981E+01
AX(9, 6)= -.5263353E+01	AX(11, 6)= -.3025013E+01
AX(9, 7)= .7019557E+01	AX(11, 7)= .3402302E+01
AX(9, 8)= -.1289197E+02	AX(11, 8)= -.4211719E+01
AX(9, 9)= .5379004E+00	AX(11, 9)= .6027898E+01
AX(9,10)= .1179493E+02	AX(11,10)= -.1179593E+02
AX(9,11)= -.5854744E+01	AX(11,11)= -.1707774E+00
AX(9,12)= .3970046E+01	AX(11,12)= .1214377E+02
AX(9,13)= -.3105573E+01	AX(11,13)= -.6395662E+01
AX(9,14)= .2662718E+01	AX(11,14)= .4616756E+01
AX(9,15)= -.2453256E+01	AX(11,15)= -.3870096E+01
AX(9,16)= .2415524E+01	AX(11,16)= .3598733E+01
AX(9,17)= -.2558527E+01	AX(11,17)= -.3678001E+01
AX(9,18)= .2999365E+01	AX(11,18)= .4219669E+01
AX(9,19)= -.4356443E+01	AX(11,19)= -.6061541E+01
AX(9,20)= .2697297E+01	AX(11,20)= .3743645E+01
AX(10, 1)= -.3743645E+01	AX(12, 1)= -.2697297E+01
AX(10, 2)= .6061541E+01	AX(12, 2)= .4356443E+01
AX(10, 3)= -.4219669E+01	AX(12, 3)= -.2999365E+01
AX(10, 4)= .3678001E+01	AX(12, 4)= .2558527E+01
AX(10, 5)= -.3598733E+01	AX(12, 5)= -.2415524E+01
AX(10, 6)= .3870096E+01	AX(12, 6)= .2453256E+01
AX(10, 7)= -.4616756E+01	AX(12, 7)= -.2662718E+01
AX(10, 8)= .6395662E+01	AX(12, 8)= .3105573E+01
AX(10, 9)= -.1214377E+02	AX(12, 9)= -.3970046E+01
AX(10,10)= .1707774E+00	AX(12,10)= .5854744E+01
AX(10,11)= .1179593E+02	AX(12,11)= -.1179493E+02
AX(10,12)= -.6027898E+01	AX(12,12)= -.5379004E+00
AX(10,13)= .4211719E+01	AX(12,13)= .1289197E+02
AX(10,14)= -.3402302E+01	AX(12,14)= -.7019557E+01
AX(10,15)= .3025013E+01	AX(12,15)= .5263353E+01
AX(10,16)= -.2911981E+01	AX(12,16)= -.4620732E+01
AX(10,17)= .3039962E+01	AX(12,17)= .4570206E+01
AX(10,18)= -.3532137E+01	AX(12,18)= -.5145857E+01
AX(10,19)= .5106700E+01	AX(12,19)= .7323482E+01
AX(10,20)= -.3158514E+01	AX(12,20)= -.4513629E+01

Table B2.1: (Continued)

AX(13, 1)= .2321094E+01	AX(15, 1)= .1724587E+01
AX(13, 2)= -.3745956E+01	AX(15, 2)= -.2780502E+01
AX(13, 3)= .2570385E+01	AX(15, 3)= .1899657E+01
AX(13, 4)= -.2178530E+01	AX(15, 4)= -.1596903E+01
AX(13, 5)= .2035754E+01	AX(15, 5)= .1473206E+01
AX(13, 6)= -.2035766E+01	AX(15, 6)= -.1445741E+01
AX(13, 7)= .2158751E+01	AX(15, 7)= .1492083E+01
AX(13, 8)= -.2428651E+01	AX(15, 8)= -.1613749E+01
AX(13, 9)= .2924533E+01	AX(15, 9)= .1831327E+01
AX(13,10)= -.3852266E+01	AX(15,10)= -.2193271E+01
AX(13,11)= .5849818E+01	AX(15,11)= .2805994E+01
AX(13,12)= -.1214043E+02	AX(15,12)= -.3929031E+01
AX(13,13)= -.9916207E+00	AX(15,13)= .6361001E+01
AX(13,14)= .1416888E+02	AX(15,14)= -.1415504E+02
AX(13,15)= -.8024489E+01	AX(15,15)= -.2652332E+01
AX(13,16)= .6312912E+01	AX(15,16)= .1966668E+02
AX(13,17)= -.5909464E+01	AX(15,17)= -.1259214E+02
AX(13,18)= .6460891E+01	AX(15,18)= .1184880E+02
AX(13,19)= -.9066290E+01	AX(15,19)= -.1560729E+02
AX(13,20)= .5570445E+01	AX(15,20)= .9462660E+01
AX(14, 1)= -.2003388E+01	AX(16, 1)= -.1468422E+01
AX(14, 2)= .3231375E+01	AX(16, 2)= .2366758E+01
AX(14, 3)= -.2211776E+01	AX(16, 3)= -.1614799E+01
AX(14, 4)= .1865759E+01	AX(16, 4)= .1354003E+01
AX(14, 5)= -.1730582E+01	AX(16, 5)= -.1244238E+01
AX(14, 6)= .1711727E+01	AX(16, 6)= .1214189E+01
AX(14, 7)= -.1786445E+01	AX(16, 7)= -.1243292E+01
AX(14, 8)= .1963144E+01	AX(16, 8)= .1330014E+01
AX(14, 9)= -.2280288E+01	AX(16, 9)= -.1486131E+01
AX(14,10)= .2829955E+01	AX(16,10)= .1740108E+01
AX(14,11)= -.3840109E+01	AX(16,11)= -.2150489E+01
AX(14,12)= .6011382E+01	AX(16,12)= .2842866E+01
AX(14,13)= -.1288503E+02	AX(16,13)= -.4124397E+01
AX(14,14)= -.1630424E+01	AX(16,14)= .6949410E+01
AX(14,15)= .1623875E+02	AX(16,15)= -.1620891E+02
AX(14,16)= -.9673128E+01	AX(16,16)= -.4539958E+01
AX(14,17)= .8141590E+01	AX(16,17)= .2583656E+02
AX(14,18)= -.8463907E+01	AX(16,18)= -.1867804E+02
AX(14,19)= .1160957E+02	AX(16,19)= .2261772E+02
AX(14,20)= -.7098181E+01	AX(16,20)= -.1349295E+02

Table B2.1: (Continued)

AX(17, 1)= .1218604E+01	AX(19, 1)= .6259911E+00
AX(17, 2)= -.1963676E+01	AX(19, 2)= -.1008507E+01
AX(17, 3)= .1338500E+01	AX(19, 3)= .6867653E+00
AX(17, 4)= -.1120320E+01	AX(19, 4)= -.5737875E+00
AX(17, 5)= .1026671E+01	AX(19, 5)= .5243805E+00
AX(17, 6)= -.9979585E+00	AX(19, 6)= -.5077366E+00
AX(17, 7)= .1016361E+01	AX(19, 7)= .5143526E+00
AX(17, 8)= -.1079209E+01	AX(19, 8)= -.5422332E+00
AX(17, 9)= .1193568E+01	AX(19, 9)= .5938412E+00
AX(17,10)= -.1377423E+01	AX(19,10)= -.6761150E+00
AX(17,11)= .1666521E+01	AX(19,11)= .8025338E+00
AX(17,12)= -.2132027E+01	AX(19,12)= -.9982880E+00
AX(17,13)= .2927455E+01	AX(19,13)= .1312360E+01
AX(17,14)= -.4435081E+01	AX(19,14)= -.1847948E+01
AX(17,15)= .7869258E+01	AX(19,15)= .2849987E+01
AX(17,16)= -.1959053E+02	AX(19,16)= -.5011197E+01
AX(17,17)= -.8782828E+01	AX(19,17)= .1092444E+02
AX(17,18)= .3913414E+02	AX(19,18)= -.3741896E+02
AX(17,19)= -.3738676E+02	AX(19,19)= -.1180539E+03
AX(17,20)= .2147473E+02	AX(19,20)= .1478040E+03
AX(18, 1)= -.9532390E+00	AX(20, 1)= -.1000000E+01
AX(18, 2)= .1535841E+01	AX(20, 2)= .1611027E+01
AX(18, 3)= -.1046218E+01	AX(20, 3)= -.1096980E+01
AX(18, 4)= .8746561E+00	AX(20, 4)= .9163862E+00
AX(18, 5)= -.8001083E+00	AX(20, 5)= -.8372943E+00
AX(18, 6)= .7757615E+00	AX(20, 6)= .8104663E+00
AX(18, 7)= -.7873224E+00	AX(20, 7)= -.8206790E+00
AX(18, 8)= .8320691E+00	AX(20, 8)= .8646710E+00
AX(18, 9)= -.9143349E+00	AX(20, 9)= -.9462406E+00
AX(18,10)= .1045817E+01	AX(20,10)= .1076212E+01
AX(18,11)= -.1249386E+01	AX(20,11)= -.1275586E+01
AX(18,12)= .1568678E+01	AX(20,12)= .1583430E+01
AX(18,13)= -.2091479E+01	AX(20,13)= -.2075143E+01
AX(18,14)= .3012883E+01	AX(20,14)= .2907738E+01
AX(18,15)= -.4838686E+01	AX(20,15)= -.4446960E+01
AX(18,16)= .9254688E+01	AX(20,16)= .7693683E+01
AX(18,17)= -.2557260E+02	AX(20,17)= -.1614893E+02
AX(18,18)= -.2212541E+02	AX(20,18)= .4856703E+02
AX(18,19)= .8368152E+02	AX(20,19)= -.3803828E+03
AX(18,20)= -.4220313E+02	AX(20,20)= .3430000E+03

Table B2.2: Shifted Legendre Matrix for Second Derivative in the x-Direction.

BX(1, 1)= .5882400E+05	BX(3, 1)= -.1953836E+04
BX(1, 2)= -.8055594E+05	BX(3, 2)= .5662292E+04
BX(1, 3)= .2891939E+05	BX(3, 3)= -.5992182E+04
BX(1, 4)= -.1047670E+05	BX(3, 4)= .2749577E+04
BX(1, 5)= .5121089E+04	BX(3, 5)= -.6528814E+03
BX(1, 6)= -.2992920E+04	BX(3, 6)= .2873912E+03
BX(1, 7)= .1968288E+04	BX(3, 7)= -.1637516E+03
BX(1, 8)= -.1409437E+04	BX(3, 8)= .1079261E+03
BX(1, 9)= .1077767E+04	BX(3, 9)= -.7832900E+02
BX(1,10)= -.8694767E+03	BX(3,10)= .6102371E+02
BX(1,11)= .7343129E+03	BX(3,11)= -.5029830E+02
BX(1,12)= -.6460976E+03	BX(3,12)= .4348839E+02
BX(1,13)= .5907143E+03	BX(3,13)= -.3925344E+02
BX(1,14)= -.5608812E+03	BX(3,14)= .3691758E+02
BX(1,15)= .5540635E+03	BX(3,15)= -.3621155E+02
BX(1,16)= -.5725270E+03	BX(3,16)= .3722436E+02
BX(1,17)= .6267042E+03	BX(3,17)= -.4059700E+02
BX(1,18)= -.7502847E+03	BX(3,18)= .4848513E+02
BX(1,19)= .1101929E+04	BX(3,19)= -.7111686E+02
BX(1,20)= -.6840000E+03	BX(3,20)= .4413114E+02
BX(2, 1)= .3519454E+05	BX(4, 1)= .4226044E+03
BX(2, 2)= -.4604504E+05	BX(4, 2)= -.8544226E+03
BX(2, 3)= .1302267E+05	BX(4, 3)= .1788586E+04
BX(2, 4)= -.3020902E+04	BX(4, 4)= -.2372512E+04
BX(2, 5)= .1289883E+04	BX(4, 5)= .1225609E+04
BX(2, 6)= -.7109194E+03	BX(4, 6)= -.2948967E+03
BX(2, 7)= .4534338E+03	BX(4, 7)= .1312063E+03
BX(2, 8)= -.3189121E+03	BX(4, 8)= -.7577494E+02
BX(2, 9)= .2411021E+03	BX(4, 9)= .5076073E+02
BX(2,10)= -.1930246E+03	BX(4,10)= -.3752541E+02
BX(2,11)= .1621487E+03	BX(4,11)= .2983255E+02
BX(2,12)= -.1421208E+03	BX(4,12)= -.2513733E+02
BX(2,13)= .1295711E+03	BX(4,13)= .2226658E+02
BX(2,14)= -.1227689E+03	BX(4,14)= -.2065222E+02
BX(2,15)= .1210871E+03	BX(4,15)= .2004943E+02
BX(2,16)= -.1249787E+03	BX(4,16)= -.2045510E+02
BX(2,17)= .1366938E+03	BX(4,17)= .2218938E+02
BX(2,18)= -.1635613E+03	BX(4,18)= -.2640814E+02
BX(2,19)= .2401504E+03	BX(4,19)= .3866205E+02
BX(2,20)= -.1490587E+03	BX(4,20)= -.2398109E+02

Table B2.2: (Continued)

BX(5, 1)= -.1524376E+03	BX(7, 1)= -.4134923E+02
BX(5, 2)= .2762192E+03	BX(7, 2)= .6969019E+02
BX(5, 3)= -.3215479E+03	BX(7, 3)= -.5788302E+02
BX(5, 4)= .9279388E+03	BX(7, 4)= .7129785E+02
BX(5, 5)= -.1330468E+04	BX(7, 5)= -.1270761E+03
BX(5, 6)= .7259727E+03	BX(7, 6)= .4394439E+03
BX(5, 7)= -.1770556E+03	BX(7, 7)= -.6753989E+03
BX(5, 8)= .7953983E+02	BX(7, 8)= .3902139E+03
BX(5, 9)= -.4642023E+02	BX(7, 9)= -.9770137E+02
BX(5,10)= .3149120E+02	BX(7,10)= .4486006E+02
BX(5,11)= -.2363412E+02	BX(7,11)= -.2679053E+02
BX(5,12)= .1912541E+02	BX(7,12)= .1867337E+02
BX(5,13)= -.1645341E+02	BX(7,13)= -.1448428E+02
BX(5,14)= .1493640E+02	BX(7,14)= .1220810E+02
BX(5,15)= -.1427255E+02	BX(7,15)= -.1105283E+02
BX(5,16)= .1439383E+02	BX(7,16)= .1072014E+02
BX(5,17)= -.1548706E+02	BX(7,17)= -.1122247E+02
BX(5,18)= .1833322E+02	BX(7,18)= .1304965E+02
BX(5,19)= -.2676328E+02	BX(7,19)= -.1886887E+02
BX(5,20)= .1658960E+02	BX(7,20)= .1167039E+02
BX(6, 1)= .7257072E+02	BX(8, 1)= .2683062E+02
BX(6, 2)= -.1253904E+03	BX(8, 2)= -.4456555E+02
BX(6, 3)= .1165803E+03	BX(8, 3)= .3468669E+02
BX(6, 4)= -.1838983E+03	BX(8, 4)= -.3743846E+02
BX(6, 5)= .5979441E+03	BX(8, 5)= .5190503E+02
BX(6, 6)= -.8938904E+03	BX(8, 6)= -.9874731E+02
BX(6, 7)= .5043006E+03	BX(8, 7)= .3547916E+03
BX(6, 8)= -.1246352E+03	BX(8, 8)= -.5568258E+03
BX(6, 9)= .5657682E+02	BX(8, 9)= .3278447E+03
BX(6,10)= -.3337843E+02	BX(8,10)= -.8316423E+02
BX(6,11)= .2293335E+02	BX(8,11)= .3867371E+02
BX(6,12)= -.1747794E+02	BX(8,12)= -.2342735E+02
BX(6,13)= .1441029E+02	BX(8,13)= .1661330E+02
BX(6,14)= -.1268410E+02	BX(8,14)= -.1316944E+02
BX(6,15)= .1184950E+02	BX(8,15)= .1141714E+02
BX(6,16)= -.1175552E+02	BX(8,16)= -.1073695E+02
BX(6,17)= .1250288E+02	BX(8,17)= .1100135E+02
BX(6,18)= -.1468923E+02	BX(8,18)= -.1261578E+02
BX(6,19)= .2135708E+02	BX(8,19)= .1810658E+02
BX(6,20)= -.1322614E+02	BX(8,20)= -.1117979E+02

Table B2.2: (Continued)

BX(9, 1)= -.1927762E+02	BX(11, 1)= -.1272551E+02
BX(9, 2)= .3172496E+02	BX(11, 2)= .2072223E+02
BX(9, 3)= -.2370449E+02	BX(11, 3)= -.1478374E+02
BX(9, 4)= .2361522E+02	BX(11, 4)= .1347962E+02
BX(9, 5)= -.2852357E+02	BX(11, 5)= -.1410455E+02
BX(9, 6)= .4220801E+02	BX(11, 6)= .1661678E+02
BX(9, 7)= -.8364560E+02	BX(11, 7)= -.2227649E+02
BX(9, 8)= .3087024E+03	BX(11, 8)= .3536802E+02
BX(9, 9)= -.4929721E+03	BX(11, 9)= -.7367860E+02
BX(9,10)= .2950143E+03	BX(11,10)= .2823168E+03
BX(9,11)= -.7586097E+02	BX(11,11)= -.4647117E+03
BX(9,12)= .3579352E+02	BX(11,12)= .2865273E+03
BX(9,13)= -.2205947E+02	BX(11,13)= -.7605563E+02
BX(9,14)= .1598693E+02	BX(11,14)= .3730141E+02
BX(9,15)= -.1303907E+02	BX(11,15)= -.2418495E+02
BX(9,16)= .1175188E+02	BX(11,16)= .1879355E+02
BX(9,17)= -.1169454E+02	BX(11,17)= -.1695558E+02
BX(9,18)= .1316077E+02	BX(11,18)= .1793617E+02
BX(9,19)= -.1870070E+02	BX(11,19)= -.2466810E+02
BX(9,20)= .1152010E+02	BX(11,20)= .1508298E+02
BX(10, 1)= .1508298E+02	BX(12, 1)= .1152010E+02
BX(10, 2)= -.2466810E+02	BX(12, 2)= -.1870070E+02
BX(10, 3)= .1793617E+02	BX(12, 3)= .1316077E+02
BX(10, 4)= -.1695558E+02	BX(12, 4)= -.1169454E+02
BX(10, 5)= .1879355E+02	BX(12, 5)= .1175188E+02
BX(10, 6)= -.2418495E+02	BX(12, 6)= -.1303907E+02
BX(10, 7)= .3730141E+02	BX(12, 7)= .1598693E+02
BX(10, 8)= -.7605563E+02	BX(12, 8)= -.2205947E+02
BX(10, 9)= .2865273E+03	BX(12, 9)= .3579352E+02
BX(10,10)= -.4647117E+03	BX(12,10)= -.7586097E+02
BX(10,11)= .2823168E+03	BX(12,11)= .2950143E+03
BX(10,12)= -.7367860E+02	BX(12,12)= -.4929721E+03
BX(10,13)= .3536802E+02	BX(12,13)= .3087024E+03
BX(10,14)= -.2227649E+02	BX(12,14)= -.8364560E+02
BX(10,15)= .1661678E+02	BX(12,15)= .4220801E+02
BX(10,16)= -.1410455E+02	BX(12,16)= -.2852357E+02
BX(10,17)= .1347962E+02	BX(12,17)= .2361522E+02
BX(10,18)= -.1478374E+02	BX(12,18)= -.2370449E+02
BX(10,19)= .2072223E+02	BX(12,19)= .3172496E+02
BX(10,20)= -.1272551E+02	BX(12,20)= -.1927762E+02

Table B2.2: (Continued)

BX(13, 1)= -.1117979E+02	BX(15, 1)= -.1322614E+02
BX(13, 2)= .1810658E+02	BX(15, 2)= .2135708E+02
BX(13, 3)= -.1261578E+02	BX(15, 3)= -.1468923E+02
BX(13, 4)= .1100135E+02	BX(15, 4)= .1250288E+02
BX(13, 5)= -.1073695E+02	BX(15, 5)= -.1175552E+02
BX(13, 6)= .1141714E+02	BX(15, 6)= .1184950E+02
BX(13, 7)= -.1316944E+02	BX(15, 7)= -.1268410E+02
BX(13, 8)= .1661330E+02	BX(15, 8)= .1441029E+02
BX(13, 9)= -.2342735E+02	BX(15, 9)= -.1747794E+02
BX(13,10)= .3867371E+02	BX(15,10)= .2293335E+02
BX(13,11)= -.8316423E+02	BX(15,11)= -.3337843E+02
BX(13,12)= .3278447E+03	BX(15,12)= .5657682E+02
BX(13,13)= -.5568258E+03	BX(15,13)= -.1246352E+03
BX(13,14)= .3547916E+03	BX(15,14)= .5043006E+03
BX(13,15)= -.9874731E+02	BX(15,15)= -.8938904E+03
BX(13,16)= .5190503E+02	BX(15,16)= .5979441E+03
BX(13,17)= -.3743846E+02	BX(15,17)= -.1838983E+03
BX(13,18)= .3468669E+02	BX(15,18)= .1165803E+03
BX(13,19)= -.4456555E+02	BX(15,19)= -.1253904E+03
BX(13,20)= .2683062E+02	BX(15,20)= .7257072E+02
BX(14, 1)= .1167039E+02	BX(16, 1)= .1658960E+02
BX(14, 2)= -.1886887E+02	BX(16, 2)= -.2676328E+02
BX(14, 3)= .1304965E+02	BX(16, 3)= .1833322E+02
BX(14, 4)= -.1122247E+02	BX(16, 4)= -.1548706E+02
BX(14, 5)= .1072014E+02	BX(16, 5)= .1439383E+02
BX(14, 6)= -.1105283E+02	BX(16, 6)= -.1427255E+02
BX(14, 7)= .1220810E+02	BX(16, 7)= .1493640E+02
BX(14, 8)= -.1448428E+02	BX(16, 8)= -.1645341E+02
BX(14, 9)= .1867337E+02	BX(16, 9)= .1912541E+02
BX(14,10)= -.2679053E+02	BX(16,10)= -.2363412E+02
BX(14,11)= .4486006E+02	BX(16,11)= .3149120E+02
BX(14,12)= -.9770137E+02	BX(16,12)= -.4642023E+02
BX(14,13)= .3902139E+03	BX(16,13)= .7953983E+02
BX(14,14)= -.6753989E+03	BX(16,14)= -.1770556E+03
BX(14,15)= .4394439E+03	BX(16,15)= .7259727E+03
BX(14,16)= -.1270761E+03	BX(16,16)= -.1330468E+04
BX(14,17)= .7129785E+02	BX(16,17)= .9279388E+03
BX(14,18)= -.5788302E+02	BX(16,18)= -.3215479E+03
BX(14,19)= .6969019E+02	BX(16,19)= .2762192E+03
BX(14,20)= -.4134923E+02	BX(16,20)= -.1524376E+03

Table B2.2: (Continued)

BX(17, 1)= -.2398109E+02	BX(19, 1)= -.1490587E+03
BX(17, 2)= .3866205E+02	BX(19, 2)= .2401504E+03
BX(17, 3)= -.2640814E+02	BX(19, 3)= -.1635613E+03
BX(17, 4)= .2218938E+02	BX(19, 4)= .1366938E+03
BX(17, 5)= -.2045510E+02	BX(19, 5)= -.1249787E+03
BX(17, 6)= .2004943E+02	BX(19, 6)= .1210871E+03
BX(17, 7)= -.2065222E+02	BX(19, 7)= -.1227689E+03
BX(17, 8)= .2226658E+02	BX(19, 8)= .1295711E+03
BX(17, 9)= -.2513733E+02	BX(19, 9)= -.1421208E+03
BX(17,10)= .2983255E+02	BX(19,10)= .1621487E+03
BX(17,11)= -.3752541E+02	BX(19,11)= -.1930246E+03
BX(17,12)= .5076073E+02	BX(19,12)= .2411021E+03
BX(17,13)= -.7577494E+02	BX(19,13)= -.3189121E+03
BX(17,14)= .1312063E+03	BX(19,14)= .4534338E+03
BX(17,15)= -.2948967E+03	BX(19,15)= -.7109194E+03
BX(17,16)= .1225609E+04	BX(19,16)= .1289883E+04
BX(17,17)= -.2372512E+04	BX(19,17)= -.3020902E+04
BX(17,18)= .1788586E+04	BX(19,18)= .1302267E+05
BX(17,19)= -.8544226E+03	BX(19,19)= -.4604504E+05
BX(17,20)= .4226044E+03	BX(19,20)= .3519454E+05
BX(18, 1)= .4413114E+02	BX(20, 1)= -.6840000E+03
BX(18, 2)= -.7111686E+02	BX(20, 2)= .1101929E+04
BX(18, 3)= .4848513E+02	BX(20, 3)= -.7502847E+03
BX(18, 4)= -.4059700E+02	BX(20, 4)= .6267042E+03
BX(18, 5)= .3722436E+02	BX(20, 5)= -.5725270E+03
BX(18, 6)= -.3621155E+02	BX(20, 6)= .5540635E+03
BX(18, 7)= .3691758E+02	BX(20, 7)= -.5608812E+03
BX(18, 8)= -.3925344E+02	BX(20, 8)= .5907143E+03
BX(18, 9)= .4348839E+02	BX(20, 9)= -.6460976E+03
BX(18,10)= -.5029830E+02	BX(20,10)= .7343129E+03
BX(18,11)= .6102371E+02	BX(20,11)= -.8694767E+03
BX(18,12)= -.7832900E+02	BX(20,12)= .1077767E+04
BX(18,13)= .1079261E+03	BX(20,13)= -.1409437E+04
BX(18,14)= -.1637516E+03	BX(20,14)= .1968288E+04
BX(18,15)= .2873912E+03	BX(20,15)= -.2992920E+04
BX(18,16)= -.6528814E+03	BX(20,16)= .5121089E+04
BX(18,17)= .2749577E+04	BX(20,17)= -.1047670E+05
BX(18,18)= -.5992182E+04	BX(20,18)= .2891939E+05
BX(18,19)= .5662292E+04	BX(20,19)= -.8055594E+05
BX(18,20)= -.1953836E+04	BX(20,20)= .5882400E+05

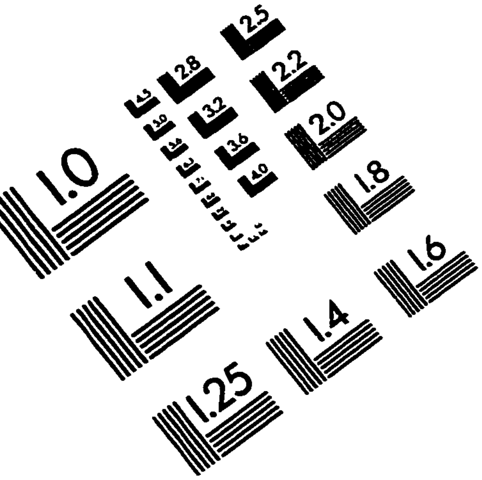
Table B3.1: Dimensionless Temperature Vector.

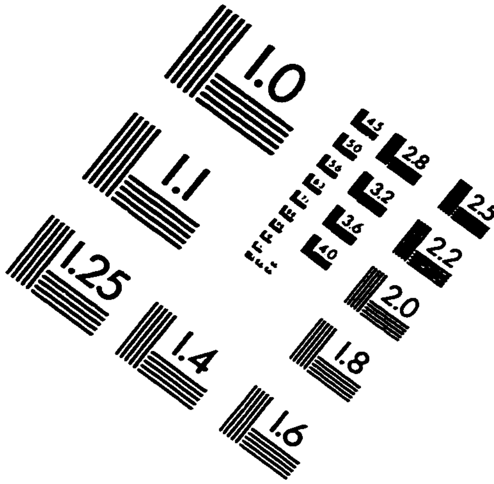
θ(1,1) = S(1)	θ(2,1) = S(12)	θ(3,1) = S(14)	θ(4,1) = S(16)	θ(5,1) = S(18)	θ(6,1) = S(20)
θ(1,2) = S(2)	θ(2,2) = Z(1)	θ(3,2) = Z(10)	θ(4,2) = Z(19)	θ(5,2) = Z(28)	θ(6,2) = Z(37)
θ(1,3) = S(3)	θ(2,3) = Z(2)	θ(3,3) = Z(11)	θ(4,3) = Z(20)	θ(5,3) = Z(29)	θ(6,3) = Z(38)
θ(1,4) = S(4)	θ(2,4) = Z(3)	θ(3,4) = Z(12)	θ(4,4) = Z(21)	θ(5,4) = Z(30)	θ(6,4) = Z(39)
θ(1,5) = S(5)	θ(2,5) = Z(4)	θ(3,5) = Z(13)	θ(4,5) = Z(22)	θ(5,5) = Z(31)	θ(6,5) = Z(40)
θ(1,6) = S(6)	θ(2,6) = Z(5)	θ(3,6) = Z(14)	θ(4,6) = Z(23)	θ(5,6) = Z(32)	θ(6,6) = Z(41)
θ(1,7) = S(7)	θ(2,7) = Z(6)	θ(3,7) = Z(15)	θ(4,7) = Z(24)	θ(5,7) = Z(33)	θ(6,7) = Z(42)
θ(1,8) = S(8)	θ(2,8) = Z(7)	θ(3,8) = Z(16)	θ(4,8) = Z(25)	θ(5,8) = Z(34)	θ(6,8) = Z(43)
θ(1,9) = S(9)	θ(2,9) = Z(8)	θ(3,9) = Z(17)	θ(4,9) = Z(26)	θ(5,9) = Z(35)	θ(6,9) = Z(44)
θ(1,10) = S(10)	θ(2,10) = Z(9)	θ(3,10) = Z(18)	θ(4,10) = Z(27)	θ(5,10) = Z(36)	θ(6,10) = Z(45)
θ(1,11) = S(11)	θ(2,11) = S(13)	θ(3,11) = S(15)	θ(4,11) = S(17)	θ(5,11) = S(19)	θ(6,11) = S(21)
θ(7,1) = S(22)	θ(8,1) = S(24)	θ(9,1) = S(26)	θ(10,1) = S(28)	θ(11,1) = S(30)	θ(12,1) = S(32)
θ(7,2) = Z(46)	θ(8,2) = Z(55)	θ(9,2) = Z(64)	θ(10,2) = Z(73)	θ(11,2) = Z(82)	θ(12,2) = Z(91)
θ(7,3) = Z(47)	θ(8,3) = Z(56)	θ(9,3) = Z(65)	θ(10,3) = Z(74)	θ(11,3) = Z(83)	θ(12,3) = Z(92)
θ(7,4) = Z(48)	θ(8,4) = Z(57)	θ(9,4) = Z(66)	θ(10,4) = Z(75)	θ(11,4) = Z(84)	θ(12,4) = Z(93)
θ(7,5) = Z(49)	θ(8,5) = Z(58)	θ(9,5) = Z(67)	θ(10,5) = Z(76)	θ(11,5) = Z(85)	θ(12,5) = Z(94)
θ(7,6) = Z(50)	θ(8,6) = Z(59)	θ(9,6) = Z(68)	θ(10,6) = Z(77)	θ(11,6) = Z(86)	θ(12,6) = Z(95)
θ(7,7) = Z(51)	θ(8,7) = Z(60)	θ(9,7) = Z(69)	θ(10,7) = Z(78)	θ(11,7) = Z(87)	θ(12,7) = Z(96)
θ(7,8) = Z(52)	θ(8,8) = Z(61)	θ(9,8) = Z(70)	θ(10,8) = Z(79)	θ(11,8) = Z(88)	θ(12,8) = Z(97)
θ(7,9) = Z(53)	θ(8,9) = Z(62)	θ(9,9) = Z(71)	θ(10,9) = Z(80)	θ(11,9) = Z(89)	θ(12,9) = Z(98)
θ(7,10) = Z(54)	θ(8,10) = Z(63)	θ(9,10) = Z(72)	θ(10,10) = Z(81)	θ(11,10) = Z(90)	θ(12,10) = Z(99)
θ(7,11) = S(23)	θ(8,11) = S(25)	θ(9,11) = S(27)	θ(10,11) = S(29)	θ(11,11) = S(31)	θ(12,11) = S(33)

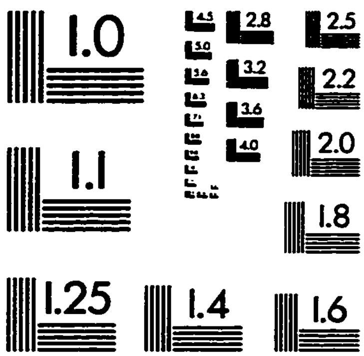
Table B3.1: (Continued)

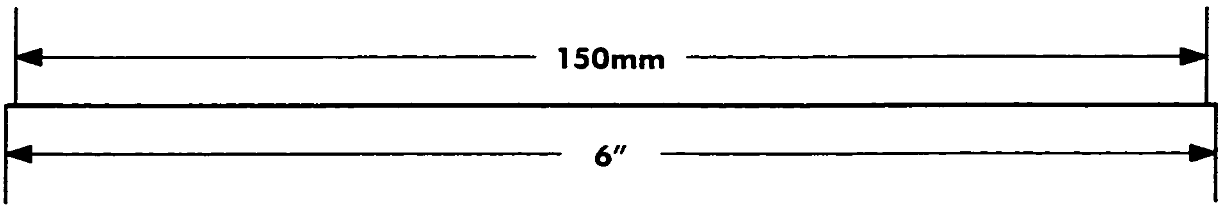
$\theta(13,1) = S(34)$	$\theta(14,1) = S(36)$	$\theta(15,1) = S(38)$	$\theta(16,1) = S(40)$	$\theta(17,1) = S(42)$	$\theta(18,1) = S(44)$
$\theta(13,2) = Z(100)$	$\theta(14,2) = Z(109)$	$\theta(15,2) = Z(118)$	$\theta(16,2) = Z(127)$	$\theta(17,2) = Z(136)$	$\theta(18,2) = Z(145)$
$\theta(13,3) = Z(101)$	$\theta(14,3) = Z(110)$	$\theta(15,3) = Z(119)$	$\theta(16,3) = Z(128)$	$\theta(17,3) = Z(137)$	$\theta(18,3) = Z(146)$
$\theta(13,4) = Z(102)$	$\theta(14,4) = Z(111)$	$\theta(15,4) = Z(120)$	$\theta(16,4) = Z(129)$	$\theta(17,4) = Z(138)$	$\theta(18,4) = Z(147)$
$\theta(13,5) = Z(103)$	$\theta(14,5) = Z(112)$	$\theta(15,5) = Z(121)$	$\theta(16,5) = Z(130)$	$\theta(17,5) = Z(139)$	$\theta(18,5) = Z(148)$
$\theta(13,6) = Z(104)$	$\theta(14,6) = Z(113)$	$\theta(15,6) = Z(122)$	$\theta(16,6) = Z(131)$	$\theta(17,6) = Z(140)$	$\theta(18,6) = Z(149)$
$\theta(13,7) = Z(105)$	$\theta(14,7) = Z(114)$	$\theta(15,7) = Z(123)$	$\theta(16,7) = Z(132)$	$\theta(17,7) = Z(141)$	$\theta(18,7) = Z(150)$
$\theta(13,8) = Z(106)$	$\theta(14,8) = Z(115)$	$\theta(15,8) = Z(124)$	$\theta(16,8) = Z(133)$	$\theta(17,8) = Z(142)$	$\theta(18,8) = Z(151)$
$\theta(13,9) = Z(107)$	$\theta(14,9) = Z(116)$	$\theta(15,9) = Z(125)$	$\theta(16,9) = Z(134)$	$\theta(17,9) = Z(143)$	$\theta(18,9) = Z(152)$
$\theta(13,10) = Z(108)$	$\theta(14,10) = Z(117)$	$\theta(15,10) = Z(126)$	$\theta(16,10) = Z(135)$	$\theta(17,10) = Z(144)$	$\theta(18,10) = Z(153)$
$\theta(13,11) = S(35)$	$\theta(14,11) = S(37)$	$\theta(15,11) = S(39)$	$\theta(16,11) = S(41)$	$\theta(17,11) = S(43)$	$\theta(18,11) = S(45)$
$\theta(19,1) = S(46)$	$\theta(20,1) = S(48)$				
$\theta(19,2) = Z(154)$	$\theta(20,2) = S(49)$				
$\theta(19,3) = Z(155)$	$\theta(20,3) = S(50)$				
$\theta(19,4) = Z(156)$	$\theta(20,4) = S(51)$				
$\theta(19,5) = Z(157)$	$\theta(20,5) = S(52)$				
$\theta(19,6) = Z(158)$	$\theta(20,6) = S(53)$				
$\theta(19,7) = Z(159)$	$\theta(20,7) = S(54)$				
$\theta(19,8) = Z(160)$	$\theta(20,8) = S(55)$				
$\theta(19,9) = Z(161)$	$\theta(20,9) = S(56)$				
$\theta(19,10) = Z(162)$	$\theta(20,10) = S(57)$				
$\theta(19,11) = S(47)$	$\theta(20,11) = S(58)$				

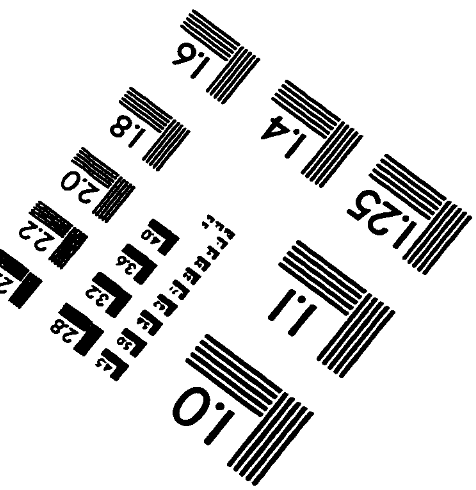
IMAGE EVALUATION TEST TARGET (QA-3)

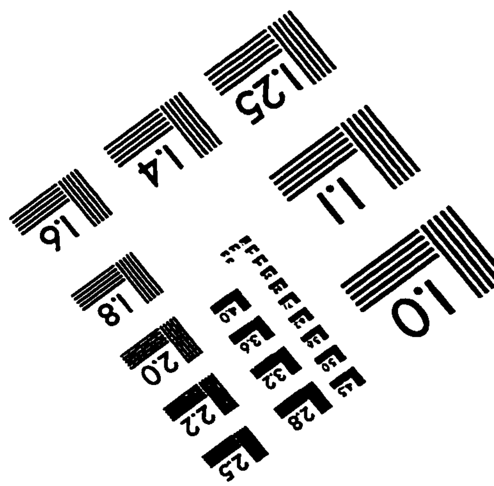












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